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A STUDY  
OF THE  
INCUBATION PERIODS  
OF  
BIRDS

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WHAT DETERMINES THEIR  
LENGTHS?

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BY

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## P R E F A C E

In the course of certain studies in ornithology, more particularly avian physiology, undertaken by the author several years ago, it early became apparent that the factors fixing or determining the length of the incubation period with different birds was largely, if not wholly, unknown.

The following pages give the results of a prolonged and detailed study of this phase of bird physiology.

The author regards all zoologic classification as a *means*, not an *end*; the classification adopted in this work is merely a means of facilitating the handling of a mass of data full of contradictions and uncertainties, and the selection of this particular bird classification was governed by a question of expediency only; obviously the author in no way wishes to be understood as believing this classification to be the best, or the only one. The author believes, however, that this classification *is* an up-to-date reflection of our present knowledge of the relation of various birds to each other.

It is inevitable that mistakes of various sorts will be found in this book; in extenuation of such errors the author trusts that his critics will recall that the labor involved in the investigations reviewed in the following pages was one of love, and carried on in the spare moments of a fairly busy professional life.

A brief resumé of pages 43 to 76 of this book was read before the Annual Meeting of the American Ornithologists' Union at Philadelphia, November 15, 1916.

It is a keen pleasure here to acknowledge, with many thanks, my obligations to the following friends, who have generously placed at my disposal incubation data, and cognate information, all of which has been invaluable in the preparation and prosecution of this study: C. W. Beebe, B. Rhett Chamberlain, L. J. Cole, E. W. Collins, L. S. Crandall, Louis Fuertes, J. D. Figgins, W. F. Kendrick, F. H. Knowlton, D. E. Lantz, F. C. Lincoln, W. DeW. Miller, R. C. Murphy, J. T. Nichols, R. J. Niedrach, Clyde Phillips, W. S. Pickrell, Robert Ridgway, A. A. Saunders, Sutherland Simpson, Witmer Stone, F. M. Watson, C. A. Watts and A. P. Wilbur.

THE AUTHOR.

Denver, Colo.,  
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## SYNOPSIS

1—Introduction: The Problem.

2—Definitions; Length of Incubation—

\* How measured.

\*\* Difficulties of fixing beginning and end.

\*\*\* True or specific length of incubation.

\*\*\*\* False or apparent length of incubation.

Types of hatching—

\* Successive.

\*\* Simultaneous.

3—The Data—

\* The amount.

\*\* The sources.

\*\*\* Explanations of conflicts in.

\*\*\*\* Obvious errors in.

4—Influences actually or seemingly altering the specific length of incubation—

\* Causing real variability.

\*\* Causing apparent variability.

5—What determines the true or specific length of incubation—

\* Past Theories:

A—The parent, or the bird itself—

(a) Its size or weight.

(b) The age of the female.

(c) Condition of the parents.

(d) Faithfulness of the parents while incubating.

(e) Longevity of the parents.

(f) Condition of young at hatching.

\* Precocious.

\*\* Altricial.

\*\*\* Completeness of development at hatching.

B—The Egg—

(a) Its size or weight.

(b) Its age or viability.

(c) Its shell.

(d) Its yolk size.

C—Telluric Conditions—

(a) Zone.

(b) Climate.

(c) Weather.

(d) Geographical location of species.

(e) Site of nest.

\*\* New Theories:

A—Body-weight: Egg-weight Index.

B—Temperature and Ascent Theory.

\* Bird temperature.

\*\* Rapidity of metabolism or "swiftness of life."

\*\*\* Temperatures, incubation lengths, and taxonomic position.

\*\*\*\* Collateral evidence.

6—Present data and this new theory.

7—Usefulness of new theory.

8—Does correlation of temperature and incubation length benefit species?

9—Data need for further study of this problem.

10—Conclusions—

A—Minor.

B—Major.

11—List of incubation periods.

12—Bibliography.

## A STUDY OF THE INCUBATION PERIODS OF BIRDS

What controls the length of incubation with birds? It is the purpose of this study to find, if possible, a correct answer to this question.

### *Introduction*

The processes going on within an egg during incubation are of fundamental and paramount importance to the species and race, in no way less than the process of fertilization; fertilization and incubation are co-equal and interdependent, and through them the time space between generations is bridged and the race perpetuated. Fertilization is governed by definite limitations and conditions. Does it seem reasonable to believe that the length of the equally important period of time necessary to complete the marvelous steps of development following fertilization is a matter of chance, a "hit or miss" duration?

It is inconceivable that such can be true; one arises from a study of the embryology of the "chick" in amazement that the wonderful and complex changes in an egg from a single cell to a peeping chicken can be brought about in a brief three weeks. Such perfection of detail, with all its potential specific and racial conditions unfolded, must surely require a fixed and definite period of time for its completion. Does it not seem more reasonable that this period of time must be relatively fixed for each species, and be controlled by factors or conditions which collectively might be called a law?

I believe that a knowledge of such factors, or such a law, is not merely academic, but, on the contrary, is of decided importance, and constitutes a block to be fitted in the mosaic being slowly put together by ornithologists, each in his day. Moreover, the writer has discovered, through his study of the question, that it is fraught with fascinating interest, and, too, opens up unexpected and wide fields for original research.

### *The Problem*

The problem in hand is to answer the question, Why does a house finch's egg take fourteen days to hatch, an ostrich's forty-two days, an emu's fifty-six days, or a hummingbird's fourteen days? It is the work of this study to analyze the published data concerning incubation periods, and to examine the explanations heretofore given, as to what governs the length of incubation, and to determine if

there be a law which controls the length of incubation, or at least to detect indications of such a law, or to point out lines of investigation which give promise of being helpful in reaching a final solution of the problem.

### *Definitions*

In this discussion the term incubation is held to mean the period of time during which heat is applied more or less continuously to a set of eggs, a period varying within a wide range according to the species; by "incubation period" is meant the whole time so involved, regardless of its duration; and by "length of incubation" is meant the number of days or weeks necessary to completely hatch the young.

The records of incubation as given in the literature on the subject embrace two varieties of lengths: (A)—the *true length* (or specific length), and (B)—the *false length* (or apparent length); the first, or *true length*, being the *minimum number of days, under optimum conditions*, necessary to hatch a normal bird, while the second is the *true length*, plus or minus the time added to, or subtracted from, it by errors in observation, or through errors caused by the different types of hatching, types to be defined later on, or plus the time added to it by such conditions as retard or temporarily suspend embryonic development. With birds which lay a considerable number of eggs in each set, and only begin to incubate when the set is completed, it is not difficult to fix the beginning of the incubation period, as with eiders (137); when, however, several eggs are laid in a set, and the female warms the first eggs more or less while the other eggs of the set are being laid, it is impossible to say exactly when the period of incubation begins, and the incubation duration has to be determined for each egg by marking it when laid.

It is almost impossible at times to decide when the parent actually begins steadily to apply the heat necessary to successful hatching. It is also extremely difficult to estimate how much heating the first eggs receive while a whole set is being laid, a fact necessitating one's defining the different types of hatching, so as to keep in mind the effects of a parent's partially heating the first laid eggs. It has been shown (92) that the domesticated pigeon's average incubation period is seventeen days, the eggs (two in a set) being laid on alternate days; the second egg usually hatches in (almost) exactly seventeen days, while the first takes eighteen and one-half days, measured from the day it is laid. If it be assumed that the real incubation begins with the laying of the second egg, it becomes manifest that the first egg receives the equivalent of one-half a day incuba-

tion while the set of eggs is being laid. That this is true cannot be questioned, since it has been found (92) by "candling" pigeons' eggs that the first egg shows indubitable evidences of beginning embryonic development by the time the second egg is laid. It is also wise here to recall that all eggs respond developmentally to lower degrees of temperature in the early parts of incubation than they do in the later or last portions.

Hence, from the foregoing, it is evident that the difficulty of fixing the real beginning of incubation must contribute not a little to conflicts in the data on incubation length, and has led to honest differences in the records made on a given species by different observers. The correct and exact method of measuring the length of incubation is to mark each egg as laid and watch it daily until hatched. This is often impossible because of psychic reasons, since a bird may abandon a nest if too closely watched, or because of physical reasons, as with birds nesting in holes. Some errors have also been caused by lack of agreement as to when the incubation terminates; thus some reports seem to indicate that the observers date the end of incubation when the egg is merely "pipped," while others fix the end when the "chick" is completely hatched.

In cases where several eggs make a set for a single hatching, all the eggs may hatch at the same (relatively) time, in which event I propose to name it a "simultaneous hatching," as is seen with the domestic hen, and when the eggs hatch one after another at intervals of a day or two, a "successive hatching." The effects of these two types of hatching on the estimation of incubation length will be considered later on.

#### *Conditions Necessary for Successful Incubation*

The growth of a new bird individual really begins directly after fertilization, which may occur a considerable time before the egg is completed and extruded; consequently, the incubation period embraces only part of a bird's embryonic development, which part is, however, by far the largest portion of the process of development.

Successful incubation depends on "keeping a fertile egg \* \* \* for a sufficient period of time under certain conditions of heat, moisture and position" (33)\*.

This combination of heat, moisture and position is achieved through the brooding of the parent (real or foster), or by a mass of decaying vegetable matter, or by hot springs, or through the care of the parents plus the sun's heat. It may begin at once, after the first egg is laid, or after part

\*Numbers in parentheses correspond to the number of the authority quoted, and as listed in the bibliography. See Table No. 2.

of a full set of eggs is laid, or only after all of a full set is laid.

I believe that the evidence permits one to hold that the *true* length of incubation varies little, if at all, with the species, however widely separated geographically, a view substantiated by the Old and New World cuckoos, and the small finches of the Northern Hemisphere and Australia. However, the work of Cole and Kirkpatrick (92) seems to show that at least with pigeons there may be a distinct, though small, true variability in the length of incubation of these birds. Whether this be a true variability, or one due to retardation of development, is unknown to me; an answer to this point must probably be reserved until further light is shed by future studies on the true lengths of incubation in other species, and the possibility of such lengths being really variable. The length of the incubation period must be measured from the time the parent (or its substitute) begins the steady application of heat to the eggs until the young bird is fully released from its shell.

### *The Data*

This study is based largely on the list of incubation period lengths incorporated in this book. See Table No. 1, which is made chiefly from lists published previously by Evans (1 and 2) and by Burns (3), together with records published singly by many others, plus those determined and given to the writer by obliging friends.

The incubation length data include records from 625 species and sub-species, scattered amongst 84 families, and representing every order of existing bird. The writer has tried to give each record in the words of the original contributor or compiler\*, and a list of all reference is given in the bibliography.

It is necessary here to note that some, perhaps many, of these records may be duplicates, an unfortunate state of affairs, but unavoidable, because some of the previous papers on the subject of this study have had no bibliographies. It were better, I believe, to include some duplicates than to exclude some original, unduplicated records, in an effort to sort out and eliminate reduplications. The present list presented now by the writer probably contains records of incubation periods of more different birds than have been gathered together in any single previous publication, a comparative wealth of material giving the writer an excuse for

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\*Inasmuch as a great deal of the literature used in this study was wholly inaccessible to the writer and had to be copied for him, he fears that some errors incidental to such transcribing will have crept in, for which he expresses his regret, however unavoidable on his part these errors may have been.

trying to solve the riddle of the cause beneath the varying lengths of incubation amongst birds.

Any attempt to draw conclusions from lists of incubation periods heretofore published seems, on preliminary examination, to be hopeless; the evidence in places is highly conflicting and inconsistent, so much so that one is at once tempted to believe the length of the incubation period is a matter of more or less chance, and controlled by no particular condition or set of conditions. Fortunately, however, years of observations on domesticated birds and a vast experience in the use of artificial incubators show that this conception cannot be true, and also show that there is an actual, or a relative, fixity of the length of incubation with such species as have been so domesticated. Furthermore, the evidence seems to show that there is no inherent or known reason why a similar specific fixity should not apply to all avian species.

It is regretted that the writer did not have personal access to a larger mass of literature, for such would probably have yielded many more records of incubation, additions which would have greatly enhanced the value of these present data, and would also have saved future students of the same problem much drudgery in a search for such data. Of the nineteen thousand or more (138) species and subspecies of birds now known to ornithologists, the six hundred and twenty-five species and subspecies given in this study form but a small per cent, which may in fact be too small on which to safely base final conclusions. A future larger and more comprehensive study of the question will alone decide this.

The conclusions in this study are based on the assumption that artificial incubator records, and such other records as show a substantial concordance, are correct, and hence justifiably available as fundamental data.

#### *Conflicts in the Data*

It seems appropriate here to consider the fact that there are many conflicts in the published records of incubation lengths, and when I have been unable to examine the original record, it has been accepted as quoted. When a record has been secured by me from an original source, it has been copied *verbatim*, excepting in a few instances where it was perfectly obvious from the context that the period had been incorrectly estimated because of errors induced by "successive hatching," and in such a case the writer has tried, carefully and impartially, to make corrections for such errors, and has listed the record as so corrected.

The conflicts in the records given for a single species are often numerous, and are accountable, many times, by errors brought about by the difficulty of measuring the in-

cubation length because of "successive hatching." With sets of eggs with which the successive hatching type prevails, it is impossible to determine how long it takes to hatch each egg in such a set unless the eggs be marked. Let us see what can (and evidently does) happen in determining the length of incubation with the robin, a species which lays one egg each succeeding day until four or six are in the nest. Occasionally the parents do not incubate steadily until all their eggs are laid, in which case it is found that all the eggs take almost exactly fourteen days to hatch, counting from the laying of the last egg. If, however, the period be dated as beginning with the laying of the first egg, it would have to be estimated as being eighteen days, a palpable error of four days. It is more common for this species to have a set of eggs hatch irregularly; it may be one on the first day, two on the second day, and one on the third day (of the hatching period), in which case no accurate knowledge of the length of incubation could be gathered without having marked the eggs for identification and individual study. Under these circumstances the first laid eggs are partially incubated by the time the last ones are deposited, causing the irregular hatching; and if the period were counted as extending from the laying of the last egg to the hour of the first hatching, the time elapsing would probably be ten or eleven days, an estimate three or four days too brief. I am convinced that many surprisingly short incubation periods (as recorded in literature) are much too brief, due to errors induced in the manner just outlined. I am confident that the length of incubation of the house finch is almost exactly fourteen days, but it could be variously estimated as ten or eighteen days with different sets of eggs if care were not taken to mark and carefully identify the eggs as they are laid and hatched. Under such conditions the larger the set of eggs, the longer or shorter in days of error may be the estimate of the length of incubation, errors (plus or minus) corresponding in days to the number of eggs in the set, or to the number of days between the laying of the eggs. The effect of partial incubation when a set of eggs is being deposited results in mixed types of hatching, an added source of conflict in the incubation length data.

On the other hand, it appears that some sets, embracing several eggs, as with the flicker (69-70), may have all the eggs hatch at once (relatively), even though the early eggs are apparently subjected to partial incubation. This may be due to the possibility that the fresher eggs (later ones laid) develop comparatively more swiftly (at the normal rate) than do the older eggs (those laid first), resulting in all breaking out at nearly the same time. The possibilities

of observation error are much smaller with eggs hatching simultaneously. The eider (137) lays six to ten eggs before starting its incubating, and all hatch on the same day; yet, if it were not known that the steady application of heat to the eggs does not begin with this duck until all the eggs are laid, six to ten days could be erroneously added to the period of incubation.

Another fruitful source of error in computing the days of incubation is brought about by influences which retard or temporarily suspend the embryonic development, *i. e.*, cooling or neglecting the eggs after they have been incubated for a while, a combination often adding several days to the *true* length of incubation, exemplified by the records of the ostrich and the albatross. It is also to be noted that many observers seem to date the end of incubation when the eggs are "pipped," while others report it as ended when the bird is fully hatched. Many periods are given approximately only, indicating, perhaps, that the observer was unable to keep daily watch of the nest, or did not deem it necessary or important to determine the length of the period with exactitude, this latter possibility being the source of much discord in the records, and giving birth to such statements as "about seventeen days" or "twenty to twenty-eight days" or "after a few weeks the young are hatched" (64).

The evidence, it seems to me, points very strongly to the existence of a *true* (*or specific*) incubation period, which under *optimum* conditions varies little with each species or subspecies; hence, if there be marked discrepancies or differences in the records of such species and subspecies, it seems reasonable to believe that the records (at least in part) in such cases are inaccurate. The records of hummingbirds and wrens are good examples of conflicts, probably to be explained on the score of inaccuracy, or error in estimating the start of incubation, for it seems highly improbable that there is a difference of four days in the period of the Ruby-throated Hummingbird and the Black-throated Hummingbird, even though they are specifically distinct, while it is more improbable that there is a difference of two days in the incubation of the Carolina and the Florida Wrens, which are but geographical races of the same species, and these remarks apply equally well to the case of the Loggerhead and Migrant Shrikes, and the Western and Eastern Meadowlarks. The Cedar Bird is a good example of how wide a difference can be found in the incubation records of a given species; the internal evidence in this instance convinces me that sixteen days is probably correct.

There are clear indications that other errors or conflicts have crept in because of typographical (or clerical) mis-

takes, as, for example, when it is recorded by one writer that the Hummingbird's incubation period is "eighty days."

There is a singular disagreement in the recorded lengths of incubation of species which might be called semi-domesticated, as the white stork, a lack of agreement inexplicable to the writer, unless it be due to faulty observation.

It is necessary, when analyzing these data, to remember that an agreement in the records quoted by two or more different authorities does not thereby mean that the records are conclusively correct because of such agreement, for one writer may have (and evidently has) copied from another without indicating or crediting such fact.

Conflicts and lack of consonance in the records of the length of incubation, and inconsistencies of testimony on the same, are not surprising; the writer's slight personal experience in trying to determine accurately the incubation period of a few species has shown him the many difficulties to be encountered and overcome in such a line of work. Many birds abandon a nest (and its eggs) if it be too closely watched, or if the nest be disturbed in the least; and to overcome this difficulty calls for limitless care and patience while observing the nest. It is a time-robbing task to visit a nest daily, it may be hourly, to ascertain when the eggs are laid, to mark them as laid, and to watch when they hatch, all of which must be done with some species if one is to succeed in making an accurate determination. Newton (25) long ago deplored the scantiness and inaccuracy of the then existing data on incubation, because (he said) correct data were greatly needed to check up and compare the embryology of different bird species at relatively the same stages, as an aid to put taxonomy on a sound basis. It is obvious that every ornithologist will concur in this, and the writer hopes to show later on that a more extensive and accurate knowledge of the true length of incubation of different species may help the taxonomer otherwise than through embryology. In justice to the multitude of bird students who have contributed indirectly and directly to the present list of incubation periods, one must recall that heretofore there has been no apparent indication of a need for exactitude in measuring the length of this period. Notwithstanding the unavoidable errors and discrepancies probably embodied in this list, it is a splendid commentary on the enthusiasm, care, patience and self-denial of ornithologists the world over that so many records have been made, many of which are patently of great accuracy.

From this brief survey of the conflicts in the data, it is evident that this list of incubation periods is made up of both *true* and *apparent* lengths of incubation, the latter probably being in the majority, and that it needs more

time and extended observations, with the idea of learning the true period of incubation, to successfully sift apart these two kinds of records.

### *Influence Altering the Incubation Length*

In this study it is assumed that the *true* length of incubation is a blastogenic characteristic, fixed for, and as such inherited by, each species; that it is comparatively inelastic, and yields exceedingly slowly to change; that with each species it embraces, under optimum conditions of "temperature, moisture and position," a fixed minimum number of days, just sufficient (and no more) to bring about the complete development and hatching of a normal bird. A striking proof of its inelasticity and prepotent inheritability is seen with domesticated birds, more particularly pigeons and chickens; for were this period plastic, under man's selection, as are the tissues, functions and habits of these birds, one would expect to find such plasticity showing itself in a patent variation of the incubation period of such domesticated birds. Man can, and has been able to cause, *or fix*, most extraordinary changes in his domesticated birds: with pigeons, not only an increase in the number of tail feathers, but even a lessening of the number of ribs (138), and with chickens, not only the almost unbelievable alteration in sizes from that of a bantam to a huge Cochin-China, but also an increase in the number of toes (the five-toed Dorkings). Man has domesticated many other birds, and if with them the period of incubation were not fixed, it seems reasonable to believe that it should have exhibited variations comparable to those variations of body, etc., mentioned above, in pigeons and chickens. Yet, if I read aright, there is not the slightest indication of any alteration in the incubation period of any of man's domesticated birds; on the contrary, all seem to adhere rightly to the ancestral characteristic as shown in congeners still wild, or in wild species most closely related. It has been definitely determined from the experience of hundreds of poultry raisers, in natural and artificial incubation, that the incubation period of the domestic hen is *almost* exactly and *almost* invariably twenty-one days: it matters not what breed, bantam or brahma, nor however remote from, or near to, the ancestral jungle fowl, the period of incubation remains the same as that of the jungle fowl, viz., twenty-one days. The same may be said, in effect, of the turkey, quail, pheasant, canary, pigeon, duck, goose and, so far as the writer can learn, all other domesticated birds.

Furthermore, birds belonging to families having a fairly similar incubation period, *i. e.*, finches, all exhibit this uniformity, even though separated by large geographic

spaces, and even possibly by geologic time-spaces; thus, the swallow and the finches of Australia still cleave to the ancestral period of their cousins of the North, and the English and New Zealand gannets have identical incubation periods.

Certainly the incubation length seems far more changeless, persistent and deep-rooted in nature than are other characteristics of birds, as, for example, the proventriculus mucosa of a gull (25). Furthermore, as has been suggested, it is not subject to selection by man, as are other characteristics, for while he has, *in effect*, changed a jungle fowl into a five-toed dorking, and a rock-pigeon into a fan-tail, still both of these species have retained their original lengths of incubation.

If the structure of the egg shell persistently tend to be characteristic, and remain the same with groups of birds, or with the species (110), why should not the far more important process of embryonic development, and its length, do likewise? While the immediately foregoing would seem to show the length of the period of incubation as a fixed characteristic, yet a superficial examination of a list of such periods leads one to believe that there is, in fact, considerable variability in the length of incubation of a given species, and unless one can learn if this be true or false, it were absolutely useless to attempt to draw conclusions from the facts published on incubation lengths, because, viewing these facts as evidence, they are in many parts hopelessly conflicting. I am convinced that most of such conflicts are to be explained by a careful study of the influences apparently affecting the true length of incubation, *i. e.*, influences causing *apparent* variability in the true length of incubation.

Variability in the length of incubation may be *true*, that is, permanently lengthening, or actually shortening, the minimum number of days for successful hatching under optimum conditions, and *apparent*, shortening or lengthening by slowing of the embryonic development by errors of faulty time measurements.

*True variability*—The writer questions very much whether there be any decided *true* variability, *i. e.*, a variability occurring when all necessary conditions are optimum. There is a small amount of experimental evidence at hand which shows conclusively that with the domestic hen it is possible, by suitable regulation of temperature conditions in an artificial incubator (33), to shorten the length of incubation a few hours only. This is well known to poultry raisers, who know also that the dividing line between successfully shortening the period and killing the embryo is exceedingly difficult to maintain, even impossible at times. All secondary influences which tend to induce this subtle influence of temperature increase, especially towards the

end of incubation, may be considered as coming under this caption. Such conditions as are quoted in nearly every poultry raiser's manual can be mentioned here; an attentive, faithful setting hen may bring out a hatching of chicks in twenty days (33), and favorable weather and a suitable nest site (104) also tend to maintain optimum temperature conditions, with *possibly* a true, but very slight, shortening of the incubation period.

This true variability towards the side of shortening the period of incubation is probably in progress *now*, the world over, with many different species, especially the higher birds, and it will be taken up in greater detail later on.

*Apparent variability*—By apparent variability I would have understood all lengthening of the specific incubation period which is merely an addition to it of days of prolonged and retarded embryonic development caused by the various factors mentioned in this discussion, or seeming shortening or lengthening due to error of determination.

Apparent or false variability is, in the greatest number of cases, merely the result of cooling the egg during incubation, which slows down the developmental pace, or it may actually suspend it for a while; in fact, the developmental process "can be suspended and held in check for several days without destruction of the germ" (33). There can be no question as to the effect of cooling the eggs while they are being incubated, because it has been proven many times (by accident or design) with the domestic hen (33) that its period of incubation can, by such cooling, be extended to twenty-three or even twenty-four days. It is probable that eggs of the lower birds can be chilled a much longer period than can those of the higher species, without killing the embryo, a fact which probably helps to explain the seemingly great variability shown in the incubation records of, for example, the emu.

There are many ways by which this cooling action occurs: a restless, inattentive hen, a cold site for a nest, conditions preventing the eggs from receiving the necessary heat properly, as too thick shells, or which permit too rapid radiation, as too thin shells, or a poorly constructed nest; eggs which are too small radiate their heat too quickly, on exposure, since they are relatively of larger surface area than are larger eggs; parents in ill health or badly nourished will not produce optimum temperature conditions.

It appears to me that all of the conditions which are outlined in this study, which apparently modify the *true* or specific length of incubation, should be taken into account in the future in all field, incubator and zoologic park work, in order that their effects may be eliminated in an endeavor to determine with the greatest possible accuracy the true

incubation period of our living bird species, especially since the opportunities for such study will grow, as time passes, fewer and fewer before the devastating onrush of civilization.

Some of these conditions as outlined above may never occur in nature, yet it is wise to bear them in mind, and to eliminate their effects when engaged in studying the incubation of any bird.

It seems clear that a definite and correct explanation of the factor or condition which determine the *true* length of incubation would long since have been reached, had the data been more abundant and more amenable to study and analysis.

Because of the several distorting influences outlined above, there have arisen a number of explanations as to what determines or fixes the length of the incubation period, explanations which are now in order for detailed consideration.

#### *Size of Bird*

Before reviewing the information bearing on this explanation of the controlling factor of incubation duration, it becomes necessary to define "size of bird." An examination of the different uses of this expression by various authors sheds no light on exactly what it means with them, and also gives no indication that all such writers mean by it the same thing. One finds the following expressions in current use: "(length of incubation) in a general way is proportionate to the bird's size" (15); "(length of incubation) varies with the size and vitality of the bird" (12); "duration of incubation in general depends on height\* of bird" (38); "according to the size of the bird the incubation period varies, short or long, with hummingbirds ten days, with ostrich fifty days" (9). "Size of bird" may mean its dimensions, or its bulk, or, by implication, its weight. It does not seem possible that past writers on this subject could have meant size as indicated by the usual linear measurements given in describing a bird, for these would lead into a maze of characters, *i.e.*, length of neck, total length, length of bill, tail, legs or body, or the standing height, which are extremely plastic and subject to such wide variation as to make it inconceivable that such shifting characters could directly influence so deep-rooted and inelastic a character as the duration of incubation; in other words, that these variable characters could be paralleled by variations in the almost changeless *true* length of incubation.

As for bulk in a bird, one must first recall that it and the usual measurements do not necessarily go hand in hand.

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\*Meaning its stature.

A good example that measurements are not of necessity indices of bulk is given by a comparison between the black vulture and the turkey buzzard, for the latter's measurements are greater than the former's, yet its bulk is less (100).

This point is mentioned as illustrating again how confusing would be bulk or measurements if considered as intimately related to, or strongly influencing, the length of incubation.

It seems to the writer that bodily bulk must have been meant when the expression "size of bird" was used; bodily bulk and weight are closely related, but both vary more or less according to the bird's age, the sex, the season of the year and the abundance of food, etc., etc.

The sequence of the steps of development in bird embryos being practically the same in all birds, it would seem reasonable to believe that the larger the bulk to be grown, the longer it should take to complete its evolution. However, it is not alone the differing bulk to be produced which may help to bring about varying incubation periods, but also the fact that many of these steps of development in different species are greatly abbreviated or jumped almost completely; hence, one can say that it is the speed and duration of the different steps in embryonic development which produces differences in the lengths of incubation.

It is quite patent that, in a general way, there is a relation between the size (or bulk) of a bird and the duration of its incubation period, yet there are so many striking exceptions that one, at best, must hold it to be only a loose and rather indefinite correlation, and probably not a relation of cause and effect, but rather an example of two effects influenced by a single underlying cause, a suggestion to be more fully elaborated later on.

Using the words "size of bird" in the rather indefinite way found in most writings, one finds some interesting conditions in its relation to the length of incubation, having in mind the prevailing notion that the larger is the bird, the longer is its period of incubation.

Notice the difference in the sizes (or bulks) of the following pairs of species, each pair being recorded as having similar incubation periods: great-tailed grackle and tree creeper, chipping sparrow and evening grosbeak, golden eagle and puffin, ostrich and kiwi. If bulk or size alone counted with these species as the controlling factor determining the length of incubation, there should be noticeable differences in the incubation periods of these birds, rather than a definite similarity, as is the case. On the other hand, it is not uncommon to find a decidedly smaller bird having a longer incubation than is found with a decidedly larger

bird, as, for example, is found with the lapwing and the domestic hen, or the killdeer and the hen.

If size or bulk controlled the length of incubation, the hen should have a much longer period of incubation than that of the lapwing or killdeer, which, however, is not the case. The domestic hen is much larger than any of the following species, lorikeet, pied-billed grebe and common tern, yet all have almost identical incubation periods.

Many birds are quite alike in size, yet exhibit marked differences in their respective incubation lengths, *i. e.*, meadowlark and upland plover, kiwi and domestic hen. The swift and the raven are recorded as having practically the same incubation period, yet how great is the disparity of their sizes! This loose relation of size of bird and length of incubation is more noticeable within the confines of natural groups (families), the Buteonidae for example, a fact which was pointed out by H. Milne-Edwards (38) as long ago as 1863, and recently Cole and Kirkpatrick (92) intimated their belief in such a relation in the pigeon family.

While it is true that this connection between bulk and incubation length is strikingly evident in some families, the contrary obtains in many others, so that one can hardly consider it a law. The lapwing is smaller than the wood-cock, but has a longer incubation period, and with the Laridae it is found that the sooty tern and the herring gull have similar incubation periods, yet are markedly different in size.

The body of at least one species of the Megapodidae is about the size of a domestic hen, yet this species' incubation period is twice as long as that of the hen. What shall one say of the several races of song sparrows, with their marked variations in size, and the incubation period of this species (including the subspecies)? It is highly improbable that the differences in these sizes are paralleled by differences in the incubation lengths.

It is impossible to explain or understand the situation which arises in considering the record of the lammergeier, the incubation period of which is given as twenty days: this species is larger than the golden eagle (159), and its short incubation period (as recorded) is inexplicable under any given theory (past or present), and the writer believes the record is incorrect.

It would seem from the above examples that there is too much lack of concordance between the bird's bulk and its incubation period to admit a controlling relation of the first over the second, even admitting that there is a loose relation between the two.

If now one assumes that by *size* of bird is meant *weight*, one has a more stable standard to go by, especially if one assume certain criteria as necessary in taking the weight.

First, shall it be the male's or the female's weight? This is decidedly important, for there is a great difference in the weights of the two sexes with many birds—it may be 20% in the ostrich, and the male prairie falcon's weight is but 33 1-3% as much as its mate; and the female European sparrow hawk (*Accipiter nisus*) is said to weigh, at times, twice as much as its mate (181). Secondly, it is necessary to take a season which may possibly have the greatest influence, if any, over the length of incubation, *i. e.*, the breeding season, for it will probably be found that a bird's weight follows most closely a normal at this time of the bird's physiological year, and hence be less fluctuating and more influential.

If now one tries to study a comparison between birds' weights and the duration of their incubation periods, there arises at once an awkward obstacle, namely, a ridiculous paucity of data on bird weights. The following list gives all the records of bird weights which have come to light in the prosecution of this study, plus those determined by the writer.

TABLE NO. 3  
*Weights of Birds in Ounces Avoirdupois*

		Weight	Authority
Ostrich ♀ .....	avg.	4000.00	141
Kiwi .....		64.00	42
“ .....		60.00	168
Emperor Penguin .....		1440.00	20
Adelie Penguin .....		42.50	20
Albatross .....		224-288.00	185
Yellow-billed Tropic Bird .....		14.00	26
Pelican ( <i>Pelicanus mitratus</i> ) .....		512.00	181
White Pelican ♂, Juv. October .....		240.00	78
Great Blue Heron .....		96-128	180
Heron ( <i>Ardea cinerea</i> ) .....		64.00	181
Wood Ibis .....		144-192	180
Domestic Duck (Rouen) ♀ .....		128.00	34
Shoveller Duck—♂—May 11 .....		17.25	78
Grey Wild Geese ♀ .....		160.00	34
Greater Snow Goose .....		80-104.00	180
Canada Goose .....		128-224.00	180
Brant .....		64.00	180
Whistling Swan .....		192-304	180
California Vulture .....	avg.	320.00	100
Gyrfalcon ( <i>Falco rusticola gyrfalco</i> ) .....		84.00	180
Prairie Falcon ♀ .....		72.00	145
“ “ ♂ Dec. 3 .....		22.30	78
“ “ ♂ .....		24.00	145
Western Sparrow Hawk ♀ July .....		4.76	78

	Weight	Authority
European Sparrow Hawk.....	5.00-6.00	181
Eastern Sparrow Hawk.....	4.00	180
Honey Eater ( <i>Parnis apivorus</i> ).....	32.00	181
American Goshawk .....	47.00	157
Hen Harrier ( <i>Circus cyaneus</i> ).....	12.00-13.00	181
Western Red-tail Hawk ♀ .....	64.00	145
"    "    "    ♂ .....	48.00	145
Buzzard ( <i>Buteo asiaticus</i> ).....	32.00-40.00	181
Western Red-tail Hawk, June.....	39.50	78
Red-shouldered Hawk .....	32-48.00	180
Swainson's Hawk ♀ .....	56.00	145
"    ".....	25.90-56.00	180
"    "    ♂ .....	40.00	145
"    "    ♀ April.....	39.00	78
American Rough-leg Hawk, Jan.....	30.37	175
"    "    " Dec.....	33.65	78
Golden Eagle.....	184.00	60
"    ".....	160-192.00	180
Bald Eagle.....	184.00	60
"    ".....	128-192.00	180
Globose Currasow ♀ Feb.....	114.00	169
Bobwhite .....	5.50-6.50	46
Scaled Quail ♀ Jan.....	7.00	78
"    "    ♂ .....	7.50	78
Grey Partridge.....	12.00-13.00	46
Capercaillie ♂ .....	184.00	135
Dusky Grouse .....	40.00-56.00	48
Ruffed Grouse.....	30.00-40.00	46
"    " ( <i>Bonasa umbellus</i> <i>umbellus</i> ) .....	18.00-24.00	180
Sage Grouse ♂ .....	128.00	48
Wild Turkey ♀ .....	avg. 160.00	78
"    " .....	160.00-288.00	49
Guinea Fowl ♀ .....	avg. 56.00	78
Ring-neck Pheasant ♀ .....	avg. 3. 36.00	108
Golden Pheasant ♀ .....	20.00-24.00	108
Domestic Hen (mixed breed).....	64.00-80.00	78
American Coot ( <i>Fulica americana</i> ) .....	16.00-20.00	180
Great Bustard .....	480.00	10
Wilson Phalarope ♀ May 11.....	avg. 3, 2.34	78
European Woodcock ( <i>Scolopax rusticola</i> ) ♀ .....	8.00-27.00	181
American Woodcock .....	6.00	95
"    "    ♂ .....	5.00-6.00	180
"    "    ♀ .....	6.00-9.00	180
Wilson's Snipe .....	4.00-5.00	180
Common Snipe ( <i>Gallinago cælestis</i> ) .....	3.00-8.00	181
Solitary Snipe ( <i>Gallinago solitaria</i> ) .....	7.50-10.00	181

		Weight	Authority
Swinhoe's Snipe (Gallinago megalia) . . . . .	6.00-8.00	181	
Jack Snipe (Gallinago gallinula) . . . . .	2.00	181	
Greater Yellow-legs . . . . .	6.00-10.00	180	
Lesser " " . . . . .	3.50-5.00	180	
Spotted Sandpiper (Actitis macularia) ♀ May . . . . .	1.53	78	
Curlew (Numenius lineatus) . . . . .	12.00-14.00	181	
Killdeer ♀ July . . . . .	3.10	78	
Kumlien Gull (Larus kumlieni) . . . . .	21.00	180	
Lesser Tern (Sterna minuta) . . . . .	2.00	181	
Band-tail Pigeon . . . . .	avg. 12.00	127	
Domestic Pigeon . . . . .	10.00	78	
Passenger " (Estopistis migratorius) . . . . .	12.00	180	
Mourning Dove . . . . .	avg. 4.50	78	
" " . . . . .	5.00-6.00	180	
Roadrunner ♂ in October . . . . .	11.00	78	
Cockatoo Parakeet . . . . .	2.88	152	
White Cockatoo . . . . .	21.25	152	
Great Sulphur Crested Cockatoo . . . . .	26.62-43.62	152	
Lesser Sulphur Crested Cockatoo . . . . .	12.25	152	
Bare-eyed Cockatoo (Cocatua gymnopis) . . . . .	19.25	152	
Molucca Cockatoo . . . . .	34.12	152	
Leadbeater's Cockatoo . . . . .	14.50	152	
Rose-breasted Cockatoo . . . . .	18.75	152	
Blue and Yellow Macaw . . . . .	37.00	152	
Great Blue and Yellow Macaw . . . . .	51.75	152	
Midget Macaw (Ara severa) . . . . .	10.12	152	
Elegant Grass Parrakeet . . . . .	3.62	152	
Alexandrine Parrakeet (Paliornis torquata) . . . . .	8.50	152	
Belted Kingfisher . . . . .	5.00-6.00	180	
Long-eared Owl, April . . . . .	11.28	78	
Barred Owl . . . . .	20.00-32.00	180	
Screech Owl (Otus asio asio) . . . . .	4.00-6.00	180	
Eagle Owl (Bubo maximus) . . . . .	112.00	181	
Great Horned Owl . . . . .	56.00	145	
" " " (Bubo virginianus virginianus) . . . . .	48.00-72.00	180	
Burrowing Owl, May . . . . .	5.84	78	
Western Nighthawk ♂ June . . . . .	2.75	78	
Sennett's Nighthawk ♀ . . . . .	2.25-3.35	177	
Pacific Nighthawk ♀ . . . . .	4.00	177	
Broad-tailed Hummingbird ♂ July . . . . .	.10	78	
Rocky Mountain Hairy Woodpecker ♂ . . . . .	2.25	78	
Hairy Woodpecker (Dryobates villosus villosus) . . . . .	3.00	180	
Downey Woodpecker (Dryobates pubescens medianus) . . . . .	1.50	180	
Williamson's Sapsucker ♀ April 8th . . . . .	1.62	78	
Red-headed Woodpecker ♀ July . . . . .	2.80	78	

		Weight	Authority
Ant-eating Woodpecker ♂ in October.....	2.75	78	
Lewis Woodpecker ♂ Aug.....	3.81	78	
Western Flicker ♂ Aug.....	4.30	78	
Kingbird ♂ July.....	1.60	78	
Arkansas Kingbird ♀ July.....	1.60	78	
Say's Phoebe ♂ June.....	.91	78	
Hammond's Flycatcher ♂ July.....	.40	78	
Horned Lark (Desert), Nov.....	1.18	78	
Townsand's Solitaire, July.....	1.40	78	
Western Robin ♀ June.....	3.35	78	
Catbird ♀ July.....	1.40	78	
Water Ousle, July.....	2.30	78	
Bohemian Waxwing ♀ avg. 11, Feb.....	2.21	175	
"              ♂ avg. 11, Feb.....	2.22	175	
Rock Wren ♂ May.....	.60	78	
Western House Wren ♀ June.....	.50	78	
White-rumped Shrike ♂ June.....	2.03	78	
Cassin's Vireo, July.....	.60	78	
Warbling Vireo, July.....	.46	78	
Rocky Mountain Nuthatch ♀ Aug.....	.65	78	
Pigmy Nuthatch ♀ Aug.....	.38	78	
Long-tailed Chickadee ♂ July.....	.40	78	
Magpie, May.....	5.34	78	
Long-crested Jay, July.....	4.00	78	
Rocky Mountain Creeper ♀ July.....	.20	78	
Orange-crowned Warbler ♂ May.....	.37	182	
Yellow Warbler ♂ May.....	.35	78	
Myrtle Warbler ♂ May.....	.50	182	
"              ♂ May.....	.42	182	
Audubon's Warbler ♂ May.....	.40	182	
Macgillivray's Warbler ♂ July.....	.40	78	
Western Tanager ♂ July.....	1.10	78	
Red-winged Blackbird ♀ (Thick-bill), June.....	1.60	78	
Red-wing Blackbird ( <i>Agelaius phoeniceus</i> phoeniceus).....	2.50-3.00	180	
Meadow Lark ( <i>Sturnella magna magna</i> ) 4.00-5.00		180	
"              (Western) ( <i>Sturnella neglecta</i> ), June .....	3.97	78	
Rusty Blackbird .....	2.00-2.50	180	
Brewer's Blackbird ♀ June.....	2.60	78	
Bronzed Grackle, May 10.....	3.87	182	
House Finch ♀ May.....	.66	78	
Arkansas Goldfinch ♀ July.....	.47	78	
Pine Siskin ♂ July.....	.43	78	
English Sparrow ♀ .....	avg. 1.05	78	
Western Vesper Sparrow ♂ Oct.....	.85	78	
"              "              ♂ Apr. 24.....	1.00	78	
Lark Sparrow ♀ .....	.95	78	

		Weight	Authority
Red-backed Junco ♂	July.....	.70	78
Cassin's Sparrow ♂	July.....	.70	78
Western Song Sparrow ♂	Feb. 28.....	.88	175
"    Tree    "    "	♀ avg. 2, Feb. 28....	.65	175
"    "    "    "	♂ avg. 3, Feb. 28....	.71	175
Spurred Towhee ♀	June.....	1.50	78
Black-headed Grosbeak ♂	June.....	1.30	78
Lark Bunting ♂	June.....	1.50	78

It will be necessary here to consider but a few comparisons of different species and their weights and lengths of incubation; the ostrich, kiwi and emperor penguin have identical incubation periods, yet their weights are two hundred fifty, four, and ninety pounds, respectively; the domestic goose and the sparrow hawk have nearly similar incubation lengths, yet the first weighs ten pounds, while the second but five (more or less) ounces; the ruby-throated hummingbird and Cassin's vireo incubate their eggs almost exactly the same length of time, yet one weighs one-tenth of an ounce and the other six-tenths of an ounce. These examples form comparisons between species of different families, where one can expect such lack of parallelism between weights and incubation periods. With species within the confines of a single family, however, equally sharp lack of correlation of weights and incubation lengths occur: the bobwhite and the grey partridge have similar incubation periods, yet their weights are as five and one-half is to twelve, and there are several species in Fringilline birds which have identical incubation lengths, but differ markedly in weight.

While the available data on bird weights is deplorably insignificant, when the species involved are compared to the total number of known birds, yet it would seem reasonable to expect more indications of a relation of weight to incubation length, if the weight fixed this length, than one finds in the data at hand. I feel that whatever relationship appears in these curves of weight is not one of cause and effect, but, as has been said before, a correlation of two effects to a third factor as an underlying single cause. The singular and suggestive fact in this phase of our question is that with man's domesticated birds with which one can see a variation of, at times, several hundred per cent. in weight, there should be no corresponding change in incubation.

It is highly desirable to have more recorded weights of birds, especially of the breeding female, since biologic characters of birds will be more and more called upon to aid in the future in solving many riddles in avian physiology. Until a much larger mass of data along these particular

lines has been accumulated, one must suspend *final judgment* on the question of how much does a bird's weight or size influence its incubation length.

#### *Age of Female*

It is well known that pullets of our barnyard fowl lay eggs averaging smaller in size than does the mature hen, and this condition also holds good with pheasant pullets; poultry men know that eggs of mean size and weight from each race of our domestic hen hatch more successfully than do too large or too small eggs, whence it might be held that the age of the female may affect the length of incubation, since it has been shown that the mature hen is apt to lay eggs near the normal for her race, which are more uniformly successful in hatching. Whether or not the larger or the smaller than normal eggs really hatch later or earlier than the average I do not know; in the absence of definite data in answer to this, the question must be left open and undecided. Possibly the age of the female really affects the fertility or viability of the egg, and not the incubation length. It is also possible that very old females may exhibit a tendency to a slowing of metabolic intensity, which would unfavorably affect the incubating temperature.

#### *Condition of Parents*

It is not possible to say, owing to the lack of exact information, if the physical condition of the male has any influence on the length of incubation with the species with which the female does all of the incubating; nevertheless, it is conceivable that old, or immature, or weak males may give the new individual in the egg a poor start, entailing perhaps a slower rate of development, resulting in a longer period of incubation.

There is no doubt in my mind but that poor health in either parent (when both incubate) would result in what amounts to a cooling of the eggs during incubation, and a resulting apparent lengthening of this period, through sluggish embryonic development, all because of the setting bird's temperature being lower than normal. While several writers mention the physical condition of the parents as being a factor in affecting the length of incubation, none has given any data, experimental or otherwise, in support of the suggestion. It must be left open and undecided.

#### *Conduct of Parents*

The assiduity (or neglect) of the incubating parents in covering their eggs unquestionably results in the eggs being hatched "on time," or "late," or "not at all." In other words, the length of incubation is unquestionably affected by the incubating bird being frightened from its nest too

frequently, or kept from its nest too long, or through the parent birds being inattentive.

This effect on incubation has long been known to poultry raisers; it is, however, an effect not altering the *true* length of incubation, but merely one of cooling and retardation of embryonic development. Such conduct of parents does not affect the true or specific incubation length.

### *Longevity*

In a valuable paper on longevity in birds, Gurney (132) suggested that there might be some relation between bird longevity and the length of incubation.

It is nearly impossible to reach any definite conclusion on this suggestion since very little is known on that variety of longevity which is most likely the only one which affects the fluctuations of bird population and their correlated biologic results. There are nearly a hundred records relating to the ages to which various species of birds live in captivity or when domesticated, but this is potential longevity. What is lacking, however, is information on the mean or average longevity, the length of life which birds attain in nature, under normal conditions of life's pressure for and against them. Brehm (132) thought that longevity was more or less correlated with size, and there are some indications that within the Class this is true, but it fails to hold good when comparing species of differing Classes.

A curve was plotted from the longevity data given by Gurney and gathered by the writer from other sources and placed in juxtaposition with the curve of incubation lengths of the same species; it showed no correlation between the two. It is safe, from the present data, to hold that length of incubation and longevity have no relation in fact, a conclusion which H. Milne-Edwards (133) reached many years ago.

### *State of Young at Hatching*

Precocious,  
Altricial,  
Completeness of development.

In these three conditions, given as determining factors affecting the length of incubation, there are more or less confused, it seems to me, two distinct ideas; the first is that of precocity in its usual sense, *i. e.*, the state of self-helpful activity and semi-independence of young birds at hatching; and the second is that of the condition of the young being well on towards completeness of development at hatching. The first conception may or may not include the second, while the second always includes the first—a newly hatched duckling is typical of the first, while a newly hatched megapod bird is typical of the second. In considering precocity

it is easiest to handle the idea at the same time with altricial conditions of the young.

Precocity and altricial characters are antipodal, and if precocity confers (or engenders) a long incubation period, it seems reasonable to expect that an altricial species should have a short period. This expectation is realized in a number of instances, the ostrich and the English sparrow being good examples. There are, however, many striking exceptions; the domestic hen and many parrots have identical incubation periods; one is typically precocious and the other is highly altricial; and yet under this explanation the first should have a long period and the second a shorter one. Most, if not all, of the Charadriidae are precocious, which ought to bring about with these species uniformly long incubation periods, yet the records clearly show a great variety of lengths of incubation with this family, just about as one would find it in any other fairly large and diversified natural group, *i. e.*, from sixteen to thirty days. Burns (3) justly calls attention to the lack of definite relation between precocity and long incubations, and altricial characters and short incubations, comparing with this in mind, ducks and large hawks, chats and sandpipers, tropic birds and gulls, all examples which in his belief disprove the correctness of the suggestion of a causal relation between precocious and altricial characters and the duration of incubation. If precociousness engendered long incubation periods, a majority of the so-called *precoce*s should have this type of incubation length. Now, if one examine the records of the lengths of incubation amongst the precocious Ratitae, Crypturidae, Phasianidae, Anatidae and others, one finds the incubation length varying from fourteen to fifty-eight days. In other words, with the so-called *precoce*s one finds a wide range of variation in the length of incubation, just as one would find with almost any other group of orders and families indiscriminately mixed together. The supposed correlation of precocity and long incubation may have arisen through a belief that the precocious birds laid large eggs, and that large eggs presuppose long incubations, but large eggs are by no means the rule with the *precoce*s, as is witnessed with the quail, hen, grouse, etc. Furthermore, this does not help this assumed explanation since, it will be shown later, the length of incubation is not closely correlated to the size of the egg.

More or less relevant to this phase of our problem is Gadow's (150) belief that there is a direct relation between the length of incubation and the nesting period. He assumes that the developmental period is made of two portions, embryonic and post-embryonic, and that the nest period covers the post-embryonic developmental stage, which is by

no means a safe assumption, since many altricial birds, and practically all the precoces, continue post-embryonic development for a good while after leaving the nest.

Gadow's conclusion is that a long nest period is preceded by a short incubation period and (inferentially) vice versa.

While the incubation and nesting periods of some birds support this view, there is also much evidence against it. The screamer and the noddy tern do not bear support to the idea. The secretary bird is reported to incubate forty-two days, yet its young do not leave the nest for six months after hatching (138), and the condor incubates fifty-six days, while its young are reported to live seven months in the nest after being hatched (154). This question can be examined in another way by making a ratio of incubation length and nest life, counting the latter with precocious birds as zero. The following list gives this ratio with a few species: Domestic hen, 21:0; house-finch, 14:14; sparrow hawk, 29:29; golden eagle, 30:35; yellow-headed tropic bird, 28:62. It seems to me that while there is much color of truth in this suggestion made by Gadow, whose eminence in zoologic work compels attention to his ideas, there is so much against the theory that judgment must still be withheld on its finality.

Under the second way of putting the explanation comes Arrigoni's (12) statement, which voices also that of Newton (25), Evans (1-2), and Claus (10). Arrigoni writes: "The period of incubation varies, and is in relation with the state of perfection in which the young are born." It is true that the young of the precoces are *physiologically* more perfect than are the young of altricial birds, but both are far from being *morphologically* perfect, and all have a long way to go before becoming so. An English sparrow's nestling is typically the opposite of precocious, yet it hatches out in fourteen days, and spends but fourteen days in the nest. I doubt if a young killdeer reaches an equal level of development in fourteen days after hatching. As a matter of fact, it takes three weeks (after hatching) for young killdeers to reach a stage of growth permitting them to follow the parents on the wing; it is ten days (after hatching) before they are able to lift their bodies off the ground with their wings alone (183).

The only birds known to the writer whose young are hatched in a condition approaching "perfection" are the megapodes, and, the writer hopes to show later on, the length of incubation with these birds is not correlated with the state of perfection at hatching alone, but rather with quite another characteristic.

Precocity seems to me to be an acquired character of expediency, found in a heterogeneous mixture of species. To many, precocity is synonymous with "lowness," and is said to be a retained reptilian characteristic, the nearer a bird to its proto-reptilian ancestor, the greater its precocity. By this token the low birds should have both long incubation periods and noticeable precocity. However, there are quite a few "low" birds which are the reverse of precocious; they are definitely altricial, *e.g.*, pelicans, water turkeys and cormorants (65). Pycraft (115) puts the facts much more clearly, and with greater truth, when he says, "When the nestling is active from the moment of hatching, the eggs have a relatively longer incubation period than in cases where the nestlings are for a long time helpless."

The writer feels justified in holding with Burns (3) that the possession of precocious or altricial characters does not confer thereby long or short incubation periods, and that they are not correlated to the length of incubation as causes to effects.

#### *Size of Egg*

Claus (10), Fürbinger (102), and Chapman (65) all state that the incubation period varies with the size of the egg. Burns (3) says it "seems to depend almost altogether on mere size or bulk" of egg, while Evans (2) in his second conclusion feels willing to hold "that within each group, the larger the egg, the longer the period."

What is meant by "size of egg"? It does not seem possible that these (and other) writers mean mere size as expressed by length and breadth, for these two dimensions cannot possibly account for, and produce, the endless variations in the shape of eggs, variations of shape which produce corresponding differences in bulk, nor does it seem possible that they believe the infinity of bulks produced by these differences in shape would be paralleled by corresponding alterations in the incubation period. If there be any relation between the size of the egg and the duration of its incubation, the writer feels that the term "size" should be taken to mean *weight*, for after all is said, these differences in measurements and shape result in corresponding variations in egg weight. If all birds' eggs were of the same specific gravity, and if there were a fixed relation between the length-breadth index and the weight, one could easily ascertain the weights of a large number of different birds' eggs, since there is an enormous accumulation of length-breadth measurements at hand, collected with infinite care, toil and patience for years by ornithologists all over the world. Unfortunately I was able to find no data available from which one can learn if all birds' eggs have similar specific gravities, though Spohn and Riddle (173) make

statements which seem to indicate that the specific gravities of eggs from differing species are dissimilar; and unfortunately, also, the length-breadth index bears no relation to the egg weight (140). The writer studied this question for some time, seeking to evolve a formula whence one could get the egg weight from its length-breadth index, but found it impossible of achievement, in which finding he is supported by Curtis (140), who says, "The shape of the egg (hen's), as measured by the length-breadth index, is negatively correlated with the weight of the egg and with the weight of each of the egg parts."

It therefore seems to me that the only datum to be used in considering this phase of the problem in hand is, perforce, the weight of the fresh egg, and the relation of the egg weight to the length of incubation will be taken up a little later on in this section, while it will be expedient now to consider, more or less carefully, the relation of mere *bigness* to the incubation length.

It is quite apparent, after a careful review of the facts, that there is a loose relation between the size of the bird and its egg; the smaller the bird, the smaller the egg, glaring exceptions noted. This parallelism is more noticeable within the confines of natural groups (families), and within these groups there is also a loose relation between the size of the egg and the duration of incubation, *i. e.*, the larger the egg (and the bird), the longer the incubation, a relation well illustrated by the Buteonidae. There are, however, families wherein this relation does not hold good, or wherein the exceptions are too noticeable to be disregarded. Thus the egg of the guinea hen is decidedly smaller than that of the domestic hen (51), yet the guinea hen has the longer incubation period; on the other hand an example is found, in the same family, where the larger egg is accompanied by the longer incubation period, *i. e.*, with the Mikado pheasant as compared with other pheasants. There is, relatively, an enormous variation in the sizes of the eggs of fringilline birds, but the great majority of this family conform more or less closely to the fourteen-day period. There are so many contradicting facts in relation to this theory that one seems impelled to believe that egg size is *not* a factor in determining the *true* length of incubation; the size of eggs varies often to a great degree in a single set, and eggs in different sets from individuals of one species differ much in size; the average measurements of eggs from the same species in different regions vary, *i. e.*, those of the Mikado pheasant (68). Nevertheless, all these variations are unaccompanied by corresponding differences in the lengths of incubation. A fact of great weight in this discussion of egg size and incubation is that, notwithstanding the remarkable

variations in the size of the eggs of the domestic hen and its different races, there is no corresponding variation in the incubation period, be the egg from a bantam or a shanghai; in other words, the jungle fowl and its bizarre descendants all retain the ancestral length of incubation, *viz.*, twenty-one days. It seems to the writer that if this length were plastic, and altered hand in hand with changes in the size of the egg, it should be strikingly apparent with the domesticated bird, especially the common barnyard fowl, yet, as a matter of fact, there is, to reiterate, not only no change to be noticed, but a tenacious retention of the primitive ancestral duration of incubation.

Poultry raisers (103) have long recognized several different factors which produce *large variations* in the size of hens' eggs, and these factors have been given by Curtis (140), as follows: Age of hen, season of laying, state of health of hen, position of egg in the egg laying period (*i. e.*, the first or the last egg laid), the rate of egg production, and lastly the food consumption of the hen. It is possible that some of these factors can have no existence with birds in the wild state, yet, on the other hand, some appear to exist with birds in natural conditions, and still seem unaccompanied by parallel changes in the length of incubation.

If egg size (indicated by measurements) be examined as to its relation to the length of incubation, one finds a complicated condition of affairs. Newton (25) says that the eggs of the guillemot (*A. troile*) are ten times the size of those of the raven, yet the incubation periods of these birds are but three to one, while the eggs of the eagle (sp?) and those of the guillemot are recorded (25) as being almost the same in size, but there is a difference of four or six days in the lengths of incubation of these two species. The incubation periods of the elf owl and of several hummingbirds are similar, yet there is a large difference in the sizes of their respective eggs. The eggs of the flamingo and some megapods are nearly alike in length and breadth, nevertheless the first incubates twenty-eight days and the second forty-two days, rather than being identical, as would happen were this egg-size control theory correct.

The above are all examples from species belonging to different families, and as Evans has stated, there is not much relation between egg size and the length of incubation outside of the boundaries of natural groups (families). There are, however, numerous exceptions also to be found within families.

The eggs of the white and the brown pelican are recorded as differing noticeably in size, but both species have the same duration of incubation. Furthermore, eggs laid by

white herons (138) in Europe are much larger than eggs laid by the same species in India, without, so far as the writer can learn, any difference in the incubation periods of the European and the Indian birds.

It is self-evident that size, when determined by linear measurements, is an exceedingly shifting datum on which to base comparisons of different incubation periods. If there be any relation between these periods and the egg size or bulk, it seems important to secure a better datum than the above, and in a fresh egg's weight, the writer believes, one has a datum beyond criticism, as to its meaning, and one which is unaccompanied by any questionable secondary considerations, and hence furnishes much more secure ground on which to build comparisons, and from which to draw conclusions.

Unfortunately, the number of recorded egg weights from different species, gathered by the writer for this study, is very small, though there are, doubtless, many others tucked away in inaccessible publications; the following list (Table No. 4) gives all those found in literature, by the writer, plus a few which were determined by him personally. An additional list (Table No. 5), is given of the weights of individual eggs occurring in sets. All weights are in ounces and pounds (avoirdupois), and, so far as known, are of *fresh* eggs, unless otherwise specified:

TABLE NO. 4  
*Weights of Bird Eggs in Ounces Avoirdupois*

	Weight	Authority
Ostrich . . . . .	48.00-60.00	10
Ostrich . . . . .	avg. 60.00	141
Emu . . . . .	20.00	10
Kiwi . . . . .	14.00-20.00	10
Kiwi . . . . .	14.00-15.00	42
Kiwi . . . . .	14.00	168
Emperor Penguin. . . . .	16.00	20
Adelie Penguin. . . . .	4.80	136
Adelie Penguin. . . . .	4.56	20
Yellow-headed Tropic Bird. . . . .	1.42	26
Loon (Sp?) . . . . .	avg. 4, 5.67	178
Black-crown Night Heron. . . . .	avg. 4 sets, 1.25	178
Mallard Duck (domesticated) . . . . .	avg. 2.83	78
Pekin Duck (domesticated) . . . . .	2.38-3.00	78
Goose (toulouse) . . . . .	avg. 6.00	78
California Vulture (estimated by W. H. B.)	10.90	10
Sparrow Hawk. . . . .	.50	56
Western Red-tail Hawk. . . . .	2.10	78
Mallee Fowl ( <i>Lipoa ocellata</i> ) . . . . .	6.50	186
Globose Curassow. . . . .	8.00	169
Domestic Turkey. . . . .	avg. 3.23	78

		Weight	Authority
Guinea Hen	.....	1.40	78
Guinea Hen	.....	1.40	51
Silver Pheasant	.....	avg. 1.50	109
Ring-neck Pheasant	.....	avg. 1.20	109
Golden Pheasant	.....	1.00	109
Reeves Pheasant	.....	.98	109
Domestic Hen	.....	1.90	78
Domestic Hen	.....	2.00	51
Killdeer	.....	.40	78
Mountain Plover	.....	avg. 3, .52	182
Common Tern	.....	avg. 4 sets, .64	178
Domestic Pigeon	.....	.50	78
Mourning Dove	.....	.40	78
Kingfisher ( <i>Ceryle alcyon</i> )	.....	avg. 3, .45	178
Long-eared Owl	.....	avg. of 2, .82	78
Screech Owl	.....	.58	67
Western Nighthawk	.....	.35	78
Broad-tailed Hummingbird	.....	avg. .02	78
Orange-shafted Flicker	.....	avg. .25	70
Kingbird	.....	avg. 4, .15	178
Arkansas Kingbird	.....	.14	178
Veery	.....	avg. 4, .10	178
Eastern Robin	.....	avg. 4, .06	178
Western Robin	.....	avg. 3, .23	78
Catbird	.....	avg. 4, .06	178
Barn Swallow	.....	avg. of 2 sets, .05	178
Bank Swallow	.....	avg. of 4 sets, .05	178
Tree Swallow	.....	avg. 4, .06	178
Cliff Swallow	.....	avg. of 3 sets, .07	178
Red-eye Vireo	.....	avg. of 2 sets, .07	178
Magpie	.....	avg. 17, .34	78
Crow ( <i>Corvus brachyrhynchos</i> <i>brachyrhynchos</i> )	.....	avg. 6, .62	78
Yellow Warbler	.....	avg. of 2 sets, .04	178
Ovenbird	.....	avg. 4, .09	178
Redstart	.....	avg. 8, .05	178
Bobolink	.....	avg. 5, .10	178
Western Meadow Lark	.....	avg. 3, .20	78
Brewer's Blackbird	.....	avg. 6, .18	78
House Finch	.....	avg. 8, .08	78
English Sparrow	.....	avg. 10, .09	78
English Sparrow	.....	avg. 18, .09	178
Western Vesper Sparrow	.....	avg. 4, .09	78
Chipping Sparrow	.....	avg. of 2 sets, .05	178
Song Sparrow (subsp?)	.....	avg. 14, .07	178
Black-head Grosbeak	.....	avg. 3, .10	78
Lazuli Bunting	.....	.07	78
Lark Bunting	.....	avg. 4, .10	78

TABLE NO. 5 (78)  
*Weights of Eggs in Sets, in Grains*

	Set	Egg Number						
		1	2	3	4	5	6	7
Killdeer .....	1	175	190	186	198	...	...	...
	2	221	214	215	229	...	...	...
Nighthawk (Western) (Sup sp?)..	..	140	128	...	...	...	...	...
Broad-tail Hummingbird.....	1	8	9	...	...	...	...	...
	2	8	...	...	...	...	...	...
Arkansas Kingbird.....	..	59	70	60	66	...	...	...
Western Robin.....	..	109	105	109	...	...	...	...
Magpie .....	1	140	140	144	140	144	144	144
	2	132	140	144	152	155	152	152
Western Meadow Lark.....	..	83	87	87	...	...	...	...
Brewer's Blackbird.....	..	79	79	83	75	83	...	...
English Sparrow.....	1	46	41	42	43	34	...	...
	2	36	40	40	38	44	...	...
Western Vesper Sparrow.....	..	38	38	34	42	...	...	...
Black-headed Grosbeak.....	..	62	60	58	...	...	...	...
Lark Bunting.....	..	56	56	56	52	...	...	...

If, now, one examined these various egg weights some interesting conditions appear: First as to isolated cases of comparisons, one notices that the ostrich and kiwi have equal lengths of incubation, yet the ostrich egg weighs three and three-quarters pounds, while that of the kiwi is less than a pound; a pigeon's egg weighs five times more than an English sparrow's (in fact the pigeon's egg is heavier than the sparrow itself) but there is only three or four days' difference in the incubation periods of these two species; the eggs of the yellow-billed tropic bird and those of the guinea hen are almost identical in weight, nevertheless these two species have incubation periods differing in length at least four days. If one make a curve of the incubation periods, arranging them according to the weights of the eggs, the heaviest first, it can be noticed that again there is a general tendency for the incubation length to shorten as the egg is lighter, but there are so many sharp deviations from the expected regularity that one suspects that there is another factor, not influenced by the egg weight, which is at work in fixing the length of incubation or at least such a second factor is working in conjunction with the effect of egg weight. This possible second factor will be discussed in the later portions of this study. Suffice it here to say, that, while this list of egg weights is one altogether too short on which to base a final judgment, which must be held for the time in abeyance, these curves and such other considerations as just outlined compel me to believe that egg weights are

only loosely related to the lengths of incubation, and both are effects of another single underlying character.

The more consideration I have given to this phase of our problem, the more incredible it seems to me that conditions as variable and elastic as the size and weight of eggs have been proven to be, can have much, if any, influence on the *true* duration of incubation, an epoch in the individual's life of the utmost importance to it and its race.

#### *Age of the Egg*

Any effect that the age of an egg may have on its incubation duration is probably correlated with the length of viability of such egg, by which term the writer would have understood the possibility of the embryo's remaining alive without the egg being incubated. Viability undoubtedly varies with the species, and too, it must be related to the number of eggs in a set, and to the time interval between the laying of the eggs in such a set. It is self-evident that, often, with the ruffed grouse, the first eggs must remain viable at least fourteen days. It appears from Crandall's observations (94) on an emu in captivity that this particular bird laid six eggs at intervals of five days each; if this were to occur in nature and all the eggs were to hatch it would show an amazingly tenacious viability for this species. Picknell (160) states that in captivity the ostrich lays twelve to sixteen eggs during a period of thirty days, and at the end of that time begins to incubate, which is another example of long viability.

I believe that eggs of the lower birds will be found to remain viable a much longer period than those of the higher birds; I doubt very much that a robin's or a hummingbird's egg would remain viable, even with extraordinary care, three or four weeks after being laid. The grounds for this belief are that long viability is probably a reptilian character, and is related to a particular phase of a bird's physiology, to be discussed later on. It is highly desirable to have this question of the duration of viability of birds' eggs thoroughly investigated. All that I could find in literature on this question was that hens' eggs remained viable up to the end of the eighth or ninth day, and those of pheasants, up to the fifteenth or twenty-first day. Inside of the limits of viability, the age of an egg (at least a hen's egg) unquestionably seems to influence the apparent length of incubation, for if fresh and old eggs be placed together in an incubator (or under a hen, it is said) (162), the fresher eggs hatch first. It also appears that the nearer the egg is to its limit of viability when placed under incubation conditions, the longer it takes to hatch.

Heinroth (162) says that some ducks sit upon their eggs at night during severe cold, to protect them until the

full set is laid, and yet that all of the set hatch on or about the same time. This statement uncovers a possibility which is of interest, and it is also one needing further investigation; it is quite possible that the first eggs laid in such a set undergo a slow but appreciable development, a speed of embryonic growth which is perhaps never quite equal to that of the later fresher eggs of the set, yet the amount of development in the first eggs make up for the lack of developmental speed and all the eggs in such a set mature at the same time. One must not forget that there is an appreciable degree of development of the embryo before an egg is laid, and that it is probable that the speed of this "uterine" development is continued at the same, or at an accelerated speed if the egg be incubated at once after being laid, and, contrariwise, if this initial development be suspended for a considerable time after the egg is laid, the developmental process is slow in speeding up and in getting under way again, all of which apparently elongates the true incubation length. It is said (49) that perfectly fresh turkey eggs, if incubated at once, hatch a "few hours earlier" than older eggs. This whole question of the behavior of fresh and older eggs, especially of wild birds, under incubation conditions needs attentive and thorough investigation, especially through the channels of experimental methods.

#### *Influence of the Shell*

How much difference, if any, variations in the egg shell make in the duration of incubation of birds' eggs under natural conditions is unknown to me, and it seems, *a priori*, that this question would be exceedingly difficult to settle. It is a well-recognized factor producing variations in the *success* of artificial incubation of hens' eggs, since all poultry raisers advise against mixing the eggs of different poultry breeds in the same incubator, alleging deciding want of success with such practice, and ascribing this to different degrees of thickness, hardness, coarseness, porosity, etc., of the shell of different breeds; this assumption probably has some truth, for these differing conditions of the shell might affect the readiness with which such eggs respond to the heat of the incubator. It is probable that shells thinner than normal would permit of too rapid radiation when uncovered, which, if prolonged, would result in the embryonic growth being slowed down, only adding hours or days to the true length of incubation, and not causing a permanent modification of this specific length. The proof that the shell of eggs of wild birds varies is too clear to be overlooked, and its possible modifying effect on the length of incubation cannot be disregarded. However, Meyer (178) has shown that the egg shell of the song sparrow can vary 46% in the weights of

the extremes of different eggs; there is no evidence of any similar variation in the incubation period of this species.

Further study on this point is to be made before one can render a verdict for or against it.

#### *Size of Yolk*

It has been suggested by Pycraft (138) that an abbreviation of the incubation period with many birds has been brought about by a gradual lessening of the "food yolk," presumably meaning that part of the egg commonly termed the yolk.

Enunciated by so keen a student and investigator, and such an original thinker, this suggestion must be considered with care and attention.

It is extremely difficult to discuss this idea in any way, both because Pycraft produces no statistical or experimental evidence in support of his theory, and because there seems to be no information available concerning the size of the yolk in various birds' eggs.

The only publication coming to the writer's hands, which throws any light on this theory is a paper by Curtis (140), dealing with the factors which influence the size, shape, and physical constituents of the egg of the common hen. In this study (a model of its kind) the yolk is shown to be the second most variable component of the egg, and that of two eggs, the yolk is relatively larger in the smaller egg; also that the weight of the yolk is not determined, for example, by the hen's weight alone but that it is markedly modified by her hereditary constitution, physical condition (state of health), stage of development (age), the season of the year, and the position of the egg in the series of eggs laid at the time. If these deductions by Curtis apply equally well to other birds' eggs, and, until shown otherwise, it is fair to hold that they do, it is difficult to see how Pycraft's suggestion can be tenable, since, in general, the shorter incubation periods are characteristic of birds laying small eggs, which, as has just been shown, have relatively larger yolks, in place of smaller yolks, as his hypothesis requires.

Pycraft mentions specifically, as having reduced yolk-size (or weight?) "razorbills, guillemots, (and) many gulls," but it is not possible to resolve this problem as it may apply to these and other species, until the relative sizes of their egg yolks be determined and the periods of incubation of these species be compared and viewed as to their relation to such yolk sizes. While judgment must be suspended also on this point, at least until a considerable mass of information relating to the size of the yolk in the eggs of different species of birds be secured, still it seems to me that this hypothesis is rather dubious.

### *Telluric Influences*

Under this caption are to be included the supposed effects of:

- A. Geographical zone
- B. Climate
- C. Weather
- D. Geographical residence of species
- E. Site of nest.

All of these have been mentioned by various writers as being conditions controlling or determining the incubation length; I am convinced that such influence any of these may have on the length of incubation is merely that of cooling the eggs and retarding the embryonic development, merely adding hours or days to the true length of incubation, which apparent length returns to the original if the retarding influence be removed.

It has been abundantly demonstrated with eggs in artificial incubation, that the duration of incubation can be extended by subjecting the eggs to temperature lower than the optimum, and that the degree and duration of the lowering of the temperature have limits, beyond which the embryo dies. Yet it is astonishing how much cooling or chilling a set of eggs will successfully withstand in incubation.

The writer has known of a set of house finches' eggs being left uncovered all night during a spell of cold weather, and yet producing a full number of normal and vigorous nestlings. The structure of the egg lends itself to resistance to too rapid cooling, for the shell, with its small "pores" full of air, and the shell membrane, together, make a good insulating medium. Brehm (quoted by Ingersoll, 110), says it requires one hour and forty-five minutes at fifteen degrees, Fahrenheit, to freeze a living egg; this means that it takes seventeen degrees, Fahrenheit, of frost for nearly two hours' exposure, to kill the developing embryo, and it is apparent that this time may vary proportionately with the size of the egg. It is well known that eggs in the later stages of incubation cannot resist successfully such low, or prolonged low, temperature as just mentioned, but that they do successfully withstand milder degrees of frost for much longer periods, especially during the early days of incubation, is equally well known.

It is also known that the incubation period of the domestic hen can be prolonged to the twenty-third or twenty-fourth day by judicious cooling during incubation. That this effect of cooling obtains during the incubation of various other birds at large is undisputed.

#### *Zone*

The writer has been unable to find any published information bearing on the possible effect of geographical zone on

the length of the incubation period, though one or two general statements have been encountered, given, however, without any detailed facts in support of the same. Newton (25) says that there have been "no observations made on the question if there be a difference in the length of incubation between polar and tropical individuals of the same species." Arrigoni (12) is the only writer whose statement on this point is definite, though it is unaccompanied by substantiating facts: he says "it seems, however, that birds of the same species which nest near the pole, and near the tropics, have equal periods of incubation" (sembra pero che gli nidificano e presso al polo e presso i tropici abbiano equale periodo de incubazione). It is highly probable that the bodily temperatures of birds (as is the case with *Homo*) vary little, if at all, with changes of zone, being, most likely, the same at the polar region as at the tropics; there is, however, some evidence which points to the possibility that atmospheric conditions may influence a bird's temperature, but the question has not yet been thoroughly studied and worked out. Nevertheless, I believe that birds, while incubating, would be able to maintain the necessary optimum incubating temperature equally well in the cold zones as in the hot zones. In this connection, one must not forget that a *large number* of birds' nests are constructed of such material and in such a manner, as to retain to the best advantage the heat applied by the parents to the eggs, facts which bear especially on the question of incubation at the polar regions, the eiders being marked examples of birds with nests built to retain heat. The huge, bulky magpie nest has a central bowl of non-conducting clay or mud, and in many nests are incorporated most excellent non-conductors of vegetable or animal matter. The chipping sparrow uses horse-hair, the writer has found a nest of the Arkansas kingbird lined with rabbit's hair and a house finch's nest lined with sheep-wool; and what better non-conductor can be found than the cotton-like mass of the hummingbird's nest?

Far be it from the writer wishing to be understood as holding that these materials are consciously selected for the purpose by the nest-builders; attention is merely called to the fact that provision to retain the applied heat is to be found in many differing nests, and the nests of the polar regions are no exceptions.

Many birds successfully go through the duties of incubation during the winter, when the forests are deep with snow, and akin to the arctic regions, yet, so far as I know, this does not seem to change their incubation period in comparison with their relatives nesting under less rigorous conditions. If the foregoing be true, it seems to me that geographical zone has no effect on the true length of incubation.

tion. It is stated by Chapman (65) that individuals of the same species living in the Tropics lay fewer eggs than do those in Northern regions, and it would be of value and help if one knew if this difference in the number of eggs is accompanied by a change in the incubation length, all of which still remains to be investigated. At the same time, it is necessary to call attention to the fact that the snow bunting's length of incubation is much out of relation to the periods of other fringilline birds, a fact possibly due to zone, or to *errors of observation*, and that Clark's crow has an incubation period which is rather long in comparison with others of its family, or its taxonomic position. One of its congeners (the Canada jay) nests during the snows of winter, and at high altitudes, too, without having an unusual length of incubation.

Some records of incubation lengths state that the eider ducks (137) have a shorter period than does the domesticated duck in warmer climate. Such statements remain to be substantiated, but still add force to the belief that, in the future, incubation lengths must be studied with an eye to eliminating such influences as slow down and prolong embryonic development, and thereby distort the true incubation period.

Heinroth (162) believes that the short periods of *Mereca penelope*, *Chen rossi* and *Dafila acuta* (which he gives as twenty-two to twenty-three days) is due to the short northern summer; granting that these periods are correct, why is the period of the teal in more southern latitudes no longer? Is the period of the Emperor penguin nearly fifty days, because it occurs in the dark, winter months? I think not.

#### *Climate*

Information on the possible effect of climate on the incubation length is absolutely lacking, so far as the writer has been able to determine. It is conceivable that a species living in a moist climate might be unsuccessful in incubation, if suddenly made to live in an arid region (or vice versa), because of its egg's structure having been adjusted for generations to a given average humidity, which adjustment fails in the new locality. While such a possibility is extremely remote under natural conditions, a similar result does occur with hens' eggs in artificial incubators in Colorado (a semi-arid region), the writer having been given to understand that failures to hatch in incubators, in Colorado, are frequently due to egg dessication. It would shed some light on this question if one knew if there were any difference in the lengths of incubation of white heron in India and in Europe, because of the two-fold effect of differing egg size, and climate.

Climate alters the size, color and many other characteristics of birds, but does it change the incubation length? This remains to be demonstrated. If it does, it is probably exceedingly slow in effect, and only through minute increments slowly accumulated, and probably *always* producing alterations on the side of a shorter *true* length of the incubation period.

#### *Weather*

It is said that varying weather conditions change the incubation period, and while the writer has found in his study of the house finch (77) that, short of actual freezing or prolonged chilling, the weather has no influence whatsoever on this species' incubation period, and Macdonald's (146) report on the incubation of the horned lark seems to point the same way, yet Job (95) states definitely that the incubation period of the quail is one day longer if the weather be very cool or wet, and Knight (105) states that he has recognized a prolongation of two to four days in the incubation periods of certain species of *Lanius* and of *Geothlypis* because of varying weather conditions. It is possible that prolonged droughts might also prolong, or, in fact, render unsuccessful natural incubation because of a tendency to egg dessication or to over-heating if the parent were compelled to leave a nest uncovered too long. I believe that if there be any difference in the length of incubation seemingly referable to weather, that future careful study of such effects will show that the *true* length is not altered, but that the change is merely one of prolongation due to cooling.

#### *Locality*

Geographical locality has been mentioned as a cause of differing lengths of incubation in similar, and in unrelated, species. I know of no indubitable support for this theory. There is no evidence that a robin's period is longer or shorter in New York than in Georgia, or Colorado, or Canada; on the contrary, all the facts seem to support the opposite idea that there is no change in the period, whatever the locality.

#### *Site of Nest*

Casey Wood (104) says that the English sparrow's incubation period "varies slightly between twelve and thirteen days, depending on the weather, the *locality of the nest*\*, and the amount of time the bird is on the nest," a variation, so far as the nest site is concerned, patently due to the varying temperatures produced by a well-sheltered or an exposed nest, the sheltered nest promoting optimum conditions and a resulting *true* length of incubation.

However, one writer (162) states definitely that site of

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\*Italics by W. H. B.

nest produces, not variability of the incubation period, but differing lengths in different species. Thus, by this explanation, the tree-nesting ducks and the European vulture (*Vulture monachus*) have long incubation periods because of their nesting places being so located as to have security from ordinary foes.

This, however, does not explain the long incubation periods of ground-nesting Anatidae, such as a goose or a swan, nor can it be reconciled with the short incubation period of a flicker, with which species the nesting place is reasonably free from intrusion by foes, or the short periods of cliff-nesting swallows.

The writer believes that *all* of these supposed influences on the true length of incubation discussed above really bring about only a retardation or a suspension of embryonic development, a suspended animation in *ovo*, as it were, and that in no way do they affect the *true* length of the incubation period, which, when distorted, is resumed with the next incubation or the following generation, granting the environmental conditions be normal. From the point of view of this study, one must carefully differentiate between a change of incubation length which is temporary, and affecting only one set of eggs, and one which is permanent, and passed on to succeeding generations.

Assuming, as one must, that chilling the eggs during incubation does produce such effects, the question must be interjected, "Do the eggs of all birds withstand equally well similar degrees of chilling?" It must be considered because, if they do not, those birds whose eggs endure successfully the longer periods and greater degrees of cooling will exhibit a greater variability in their incubation periods, the same being a source of perplexity in studying the problem in hand.

As has been intimated before, I believe that it will be found by future investigations (if it has not already been so determined) that eggs of the more primitive birds will remain viable under adverse conditions much longer than will those of the higher birds under like conditions; in other words, under like conditions of cooling, rough usage and neglect, a duck's egg will be viable long after a robin's egg will be spoiled. I doubt if thrushes', warblers', finches' and swallows' eggs would hatch if subjected to a course of treatment as was given to some eggs of "shore birds" by Beebe (114). This observer gathered a number of eggs of terns, skimmers, gulls, green herons (all the eggs being well on in the incubation stage) for purposes of embryologic study, which were carried about for several days without any suspicion of their remaining viable; yet several hatched on being placed in an incubator, and produced normal "chicks,"

which grew to maturity. This experience discloses but one more of the many interesting points embraced in this problem, which are yet to be thoroughly studied and settled.

### *New Explanations*

Body-weight: egg-white index, and incubation length.

Newton (25) says that "the size of the egg is generally, but not at all constantly, in proportion to that of the parent," attributing this relation to the necessity of the parent being able to completely cover and incubate all the eggs it lays in a set. This relation between the size of the body and of the egg is only general. It is also true, in a loose way, that the smaller is the bird, the smaller is its egg. There are many notable exceptions to be found on either side of the equation; the kiwi (168), megapods (16), some gallinaceous birds, and the barbary duck (161) lay eggs very large in proportion to their bodies, while with storks, cuckoos and several other species the reverse holds true.

These facts, and my own study of the weights of birds and their eggs, suggested to me that there might be some relation between the ratio of these two weights and the length of incubation of the egg. This possibility was investigated far enough to demonstrate that there is not the least relation discernible between the two, hence it is mentioned here, only to be dismissed.

### *A New Explanation Based on Physiologic Grounds*

Most of the explanations previously propounded seem inadequate, and more or less illogical, because they have been based on passive conditions, such as an anatomical character (size of body), or on a histologic character (size of egg), or have been built on effects which merely retard or suspend embryonic development, effects which do not alter the *true* or *specific length of incubation*. None has been directly correlated with an active biologic or a physiologic process or condition, which alone, it seems to me, can directly modify so vital a span as is the *true* duration of incubation.

Only two of these past theories have been founded on physiologic grounds—longevity and the health of the parents. The first cannot at present be said to have any bearing at all on the duration of incubation, and the second is inseparably related to another which seems to have an all-important influence on the true length of incubation, a condition now to be taken up and discussed.

It is hard to realize that a *fertilized egg* is, during incubation, not an organ or a detached part of a *preceding* bird, but that it is in reality a *growing new individual*, and as such must respond, or be subject, to control by special

biologic and environmental conditions, which probably are peculiar for each family, or perhaps for each species.

This is not an idle fancy, for it has been shown by experimental investigations (156) on the temperature of developing bird embryos that "the embryo of a chick must be looked upon as a cold-blooded animal" during the early days of incubation, and that later it shows more and more characters of a warm-blooded animal. If this contention be correct, then the fertilized egg, as such a new individual, must be, in its growth, fitted, and respond, to conditions peculiar to it and its immediate ancestors. In other words, it must be in consonance with its environment, and react to, and be affected by, it as in any other individual. The physiology of the embryo is determined both by its heredity and its environment. Would it not be logical to look for the factor or factors, condition or conditions, which fix the *true length of incubation* amongst the environmental conditions which make for or against the health of the developing new bird? Would it not be wiser to seek for an answer to our problem in the domain of the bird's physiology?

It has already been stated that, for an egg to be successfully incubated, it must be subject, during incubation (a) to a correct position, (b) to an atmosphere of proper moisture content, and (c) to a certain degree of temperature.

The attainment of a correct position for the egg during incubation is apparently automatically brought about by the movements of the incubating parent with all birds except the megapods. It seems undecided whether these singular birds do or do not visit or disturb an egg after it is laid.

The proper amount of moisture necessary for the preservation of the embryo is probably attained by selection, through a long process of adaptation to the surrounding prevailing humidity: it would be valuable to know if eggs of individuals of the same species, incubating in humid and in arid regions, exhibit different egg shell structure in order to compensate for humidity differences in such antipodal regions. It is possible that in natural incubation the moisture emanating from the incubating parent's body, or from the soil under a ground-nesting species, also may be a factor, and help combat undue dessication during incubation. It is said that the Egyptian plover (*Pluvianus aegyptius*), whose eggs are partly incubated by the direct heat of the sun, dampens its egg by contact with its previously water-soaked feathers.

The first of these two requisites seems to be one of pure physics only, and the second one largely of physics, with perhaps an added element of physiology.

How important is the first in natural incubation I am

unable to state; nevertheless, it seems important in artificial conditions, since most poultry raisers insist that with hens' eggs in artificial incubation it is very essential. The second is obviously a *sine qua non*, yet being largely one of physics, it does not seem in reality to affect the length of incubation, but rather the *life or death of the embryo*. Hence, since neither of the first two essentials for successful incubation is one of a bird's physiology, it remains to take up the last, and since the heat applied to eggs in natural incubation emanates from the setting bird, it would appear that the factor of the degree of temperature applied to the eggs is one of pure physiology, a question of the production and application of animal heat. Moreover, it can be said, without fear of contradiction, that temperature is the most important of all the three factors (or conditions) just enumerated. Now, inasmuch as the incubation heat comes from the brooding parent (true or foster), excepting with the megapods and (possibly for a part of daylight hours) with ostriches and the Egyptian plover, it would appear that the bodily temperature of the incubation parent should be a highly important factor in relation to the incubation period. In brief, it seems to me that birds' temperatures should be investigated, not only as such, but also as to any relation they may bear to the incubation period, and also any other facts cognate with birds' temperatures.

If a bird's temperature be highly necessary to successful incubation, it would seem reasonable to predict that birds have acquired *habits*, and *conditions of body* exhibited only during incubation, which are calculated to facilitate the application of, and conserve, the heat applied to the eggs during this period.

A superficial consideration of birds' nests throws some light on this question. While a goodly number of nests are too flimsy, or in too close contact, apparently, with the earth to aid in concentrating the heat applied to the eggs, nevertheless a majority of nests are so constructed as to retain this heat most advantageously. It is obvious, however, that nests may have been developed, and probably did arise, as a protection to, and receptacle for, the eggs, yet the almost innumerable instances where the nest materials are ideal as insulating media show that out of this primary use of a nest has grown the concomitant result of the conservation of the all-important heat applied during incubation.

Reciprocally there are conditions normal to the bird, or found only during the incubation time, which lend themselves to the application of a maximum amount of the parent's heat to its egg, and to holding this heat at the most advantageous level. Lucas (10) has maintained that the majority of birds have no feathers on the abdominal area

in order to more successfully incubate their eggs, saying "the bare spaces of the body of a bird are adaptive \* \* \* (the) belly (is) bare in most birds because of incubation, and in ducks, penguins and auks becomes bare during incubation." Pycraft draws attention to a further step in this process, and says that the bare abdominal area becomes *seemingly* inflamed, with its blood vessels more distinct than normal, a condition not likely to be a true inflammation, but a functional hyperaemia only, resulting in a more plentiful and more frequently renewed blood supply to the parts, in the end maintaining more easily the optimum incubation temperature.

Before entering upon a larger consideration of bird temperatures and their relation to the length of incubation, it seems desirable to consider briefly a few facts concerning the effects of heat applied to viable eggs.

There is a small amount of development in a fertile egg before it leaves the body of the parent, but it is very slight, and never reaches any advanced stage as is the case with many near relatives of birds, the reptiles, with which animals incubation of the egg frequently goes on to completion within the body of the female, and the young are born alive, resulting in the fact that while many reptiles are ovoviparous, birds are never anything but oviparous. The slight development in an egg which starts and goes on while it is still within the female's body continues for a while at a very slow rate after the egg is extruded, even under comparatively low temperatures, viz., 86° F. (38). Prolonged or excessive *chilling* or *over-heating* promptly kills the embryo. And both of these effects are persistently avoided by incubating parents; thus ducks, etc., cover their eggs with down or feathers when leaving the nest in cold weather, and the ostrich shades its eggs with its body and wings from the sun's excessive heat (160).

It is demonstrated that there *is* an *optimum incubation temperature*, and it is almost demonstrated that each species of domesticated bird has an optimum of its own, an optimum which hatches the eggs in the shortest time possible, and which probably varies little, if at all, with each species.

Nevertheless, it is extraordinary how, for example, a hen's egg will hatch under what *seem* anything but optimum conditions; thus, such eggs have been known to hatch in a barn-yard manure pile (33).

H. Milne-Edwards gives the optimum (without designating for what species) as 104° F. Various other figures have been given for this incubation optimum, a conflict arising, most likely, because the optimum differs with differing species.

There is support to the further idea that the optimum may vary according to the stage of the incubation. Job (95) says that for ducks (sp?) the best temperature during most of the incubation is 103° F., and slightly before or at hatching it is 104° F. One might predict this. It is a fact that with many birds, as the incubation period nears its close, the bird's belly becomes more and more bare, permitting a closer and closer contact of parent to eggs, a condition facilitating heating of the eggs; and, too, that towards the close of incubation the eggs themselves, especially in a large set of eggs, produce and disseminate heat (160); these two facts forming a combination calculated to subject the eggs to a gradually rising temperature as the incubation nears completion.

Furthermore, on the basis of what is known about avian (embryonic and post-embryonic) temperatures, this gradual rise of the incubation temperature would square with what goes on within the egg as it is incubating. I am not doing violence to the facts, nor yet making an overdraft on the imagination, in believing that a new bird, in its embryonic development, climbs up a series of evolutionary levels, from low to high, and that under these circumstances one would expect to find lower temperatures more fitting to the early parts of the incubation period, and higher temperatures in the later portions of the period, differences which may be slight, yet none the less significant. The optimum incubating temperature (in artificial incubation) for the domestic hen is given as 102° F. (early) and 103° F. (late) (33); for ducks (sp?) for the first three weeks as 102° F., and the last week 103° F. (34); for the ostrich 101° F. (160), and for the rhea (*Rhea Americana*) as 103° F. (13).

There is a large field for research in this question of temperatures of artificial incubation; there is also an engaging and unexploited field for investigation in the temperature conditions of the nest in natural incubation; special thermometers have been constructed to register this temperature, but the data are too few to require special notice here. This method of study might be undertaken with the aid of the ordinary clinical thermometer, and it remains to, and should, be vigorously prosecuted.

While it is known that there is a slight upward swing of the optimum temperature towards the end of artificial incubation, it has not yet been demonstrated in natural conditions. Still so much points to the high probability of its existence also in natural incubation that one can safely accept it as tentatively demonstrated.

If there be an optimum incubation temperature, which varies with the species and, also, according to the degree of embryonic development in the egg, it would seem safe

to predict that differing bird species should exhibit, under normal conditions of health, differing body temperatures, and perhaps, in a given individual, this normal temperature should be found to vary according to the stage of incubation, since the parent's body heat is that which develops its embryo in practically all of the myriads hatched each year.

It then becomes self-evident that the *optimum incubation temperature for any species is the temperature of the incubating parent* (true or foster).

The physiology of a bird's temperature is not nearly so well known as that of man and other warm-blooded animals, but there is, nevertheless, enough information on the subject to enable one to get a fairly comprehensive view of its physiologic characteristics.

Birds are homiothermic; they have in health a body temperature which is relatively characteristic and of a constant curve, one peculiar to the family, the genus, or possibly even to the species. This temperature, with all species so far studied, has a daily swing, being highest, with diurnal birds, between noon and six in the evening, and lowest between midnight and six in the morning, these extremes being reversed with nocturnal birds (167). The amplitude of this daily temperature swing varies with different species, and seems to be correlated more or less closely with the bird's size, since Simpson (167) found it to be widest with small birds and narrowest in large birds, there being 7.68° F. between the extremes with a thrush, and 1.65° F. for a duck, and with birds of intermediate size this swing was intermediate in amplitude. This daily swing of body temperature corresponds fairly closely with the bird's activity, being lowest when it is at rest, *i. e.*, the hen's temperature is lower while incubating than when active; it remains nearly constant during most of the period of incubation, and rises only when the hen becomes more active and "excited" at the hatching of the eggs. It is said (164), however, that the temperature of the nest is lowest in the first week of incubation and highest at the end, a change possibly not due to the hen's temperature alone, but also to the eggs themselves producing heat as the embryos develop. This twenty-four hour rise and fall of temperature also obtains with man, and is also slightly correlated with his condition of activity or rest; the curve can be reversed if his daily mode of life be reversed, a fact throwing light on the reversed curve in nocturnal birds. There is some evidence at hand showing that the female carries a higher temperature than the male (165-167), since with cormorants, guillemots, razorbills and ducks the females have the higher temperature, the excess varying between .07° F. and .5° F. This difference may seem negligible, but it must be noted and borne in mind

when investigating this subject. It has been determined that a hen's temperature varies *slightly* with the season, highest in the summer, and nearly, or exactly, identical in May and October. I am inclined to believe that there is a tendency to an increase of temperature during the mating season, since I have found the cock ring-neck pheasant's temperature much higher than the female's at this time of the bird's physiological year, and Pickrill (111) says that there is an increase of about 2° F. at such times with both sexes of the ostrich. Ingestion of food and muscular activity elevates (slightly) the temperature in man (156) and seems to do so also in birds. The support to this latter statement is indirect only. A setting hen's temperature (166) is lower than that of an active "control" hen, and the "control's" temperature is lower at night, as shown if taken when the bird is gently lifted at night from the perch. An under-fed or a starved hen (165) has a lower temperature than the normal control bird; this difference borders closely, however, on the domain of pathology, into which it is inexpedient here to enter.

Birds have bodily temperatures which are only slightly affected (156) by climate. Individuals of the same species in the Arctic region have the same temperature as those in temperate zones, showing the wonderful control of body temperature by the heat centre of the central nervous system, and nothing shows more vividly the power of this control than the experimental demonstration that a sparrow, with its feathers all clipped off, maintains its body heat, under ordinary temperatures, quite easily at normal.

The age of a bird has no relation to its body temperature, except that altricial birds do not acquire a stable and normal temperature curve until ready to leave the nest, or at least until muscular co-ordination is nearly or quite perfected. Precocious birds seem to have a perfectly functioning temperature controlling centre at hatching, while concerning the age and temperature, it may also be said that ducks varying in age from four to twenty-four months exhibited temperatures identical with those of older birds (165). The rectal temperature of a hen, taken immediately after it has laid an egg, is said to be 2° F. higher than normal (164). I am unable to say that all these peculiarities of a hen's temperature apply also to all other birds, but until shown otherwise, it is necessary to hold that they do. The normal temperature of man is assumed to be the average of the highest reading of the twenty-four hours, utilizing as large a series of observations as possible, and all of normal adults. Comparative physiology demands the same standard in other homoiothermic animals, having, of course, due regard for individual peculiarities (i. e., nocturnal animals

and birds). Therefore, in this discussion, a bird's normal temperature will be taken to mean, not the mean of the records of twenty-four hours, but the highest in that period, or the average of such highest records; hence, the most desirable bird temperature records are those taken between noon and six in the evening, accompanied by notes as to the bird's sex, age, method of securing the bird, and of other modifying factors, some of which have just been outlined.

The way of securing a bird to take its temperature varies, and it *may* have considerable influence on the result. Sea birds were caught with a baited hook and line for such purposes, nearly a century ago (165). I have found, using trapped English sparrows, that the rectal temperature of these birds is the same before and *directly* after being shot, and Simpson (165), in studying other species, antedated me in this conclusion more than thirteen years. This conclusion is also true of flickers, since a male's temperature, directly after being shot, was 106.6° F., while that of a female, taken alive (and afterwards liberated), was 106.4° F.

This method of securing animal temperatures is approximately accurate, and is substantiated by similar methods with mammals (156); in all cases, care must be taken to note if the specimen bleed profusely (becomes exsanguinated), in which case there would be a swift descent of the temperature, or if the brain be extensively damaged, in which event it is possible that the temperature might be, for a short time, abnormally high. Whatever the method of securing a bird, a standard self-registering clinical thermometer should be used, inserting it into the bowel a half-inch or more, according to the bird's size, and held in place *until the mercury ceases to rise*.

It seems self-evident that the ideal time to secure bird temperature records would be while a bird is incubating, but this, at present, would be difficult to do to any extent large enough to be useful, and the next best time to take birds' temperatures would be while they were breeding or in the brooding period. For the purposes of this study, any and all recorded bird temperatures must be utilized, even if all have been taken with little or no regard to their bearing on the length of incubation or to their relation to the peculiarities of the daily temperature curve. The number of published temperature records of birds is not large; aside from some records scattered through the literature of human and comparative physiology, and a few determined by myself, there are two principal sources of information on this subject, the first being found in a list given by H. Milne-Edwards (38), in 1863, and the second, a brief but highly suggestive study published by Sutherland in 1899 (112).

Table No. 6 gives all the above mentioned records, plus a few scattered in other publications, some given to me by obliging friends, and a few determined by myself.

TABLE NO. 6  
*Bird Temperatures in Degrees Fahrenheit*

	Weight	Authority
Ostrich, laying season ♀ .....	102.0	141
Ostrich, non-laying .....	100.0	141
Ostrich, breeding ♂ .....	104.0	141
Ostrich, average of five individuals.....	99.2	156
Ostrich, highest of five individuals.....	100.0	156
Emu .....	102.2	112
Emu .....	avg. 103.1	165
Cassowary .....	102.56	112
Tinamou (Spotted).....	avg. 104.06	112
Tinamou (Rufous).....	105.44	112
Apteryx (Mantell's) .....	99.32	112
Apteryx (Haast's) ♂ .....	100.22	112
Penguin ( <i>Eudyptula minor undina</i> ), Alive .....	avg. 6, 101.3	153
Penguin (Species?) .....	102.2	10
Penguin (Adelie) .....	102.5	10
Horned Grebe ( <i>Colymbus auritus</i> ).....	105.26	165
Albatross (Sp?) (Taken in 1836 and 1837) .....	mean 103.82	165
Albatross (Sp?) .....	104.09	38
Diomedia ( <i>exulans</i> or <i>chlorhynchos</i> ?) .....	mean of nine 105.27	165
Grand Albatross (taken in 1836 and 1837) .....	mean 102.92	165
Petit Albatross (taken in 1836 and 1837) .....	mean 106.16	165
Pétrel (Sp?) .....	103.1	38
Grand Pétrel Noir (taken in 1836 and 1837) .....	mean 103.46	165
Procellaria gracilis .....	101.66	165
Procellaria capensis .....	103.5	165
Mutton Bird ( <i>Neonectris tenuirostris brevicaudis</i> ), alive.....	avg. 7 juv.-100.2	153
Procellaria pelagica (Storm Petrel).....	103.64	165
Pétrel gris (taken in 1836 and 1837) .....	mean 103.28	165
Pétrel damier (taken in 1836 and 1837) mean	105.26	165
Cormoran (Sp?) .....	106.16	38
Phalacrocorax carbo (Cormorant) .....	mean 103.5	165
Phalacrocorax graculus (Shag) .....	mean 106.4	165
Sula bassana (Gannet) .....	mean 106.6	165
Black-Crown Night Heron ♂ May 2, directly after being shot.....	102.3	182

	Weight	Authority
Heron (Sp?) .....	105.8	156
Héron (Sp?) .....	105.8	38
Merganser (Sp?) .....	mean 106.75	165
Duck (Sp?) (24 individuals) .....	avg. 107.8	156
Mallard Duck (tame, three removes from wild) ♂ .....	mean 106.7	165
Mallard Duck (tame, three removes from wild) ♀ .....	mean 106.88	165
Domestic Duck ♂ .....	avg. maximum 107.24	167
Domestic Duck ♀ .....	avg. maximum 109.4	167
Domestic Duck ♂ .....	avg. of fifty 107.5	165
Domestic Duck ♀ .....	avg. of sixty 108.0	165
Canard commune .....	109.58	38
Duck (Sp?) .....	105.08	10
Anas rubripes (Black Duck) .....	mean 106.34	165
Aix sponsa (Wood Duck) .....	107.6	165
Canard Millouin (Pochard?) .....	108.68	38
Marila affinis .....	mean 106.2	165
Eider Duck .....	108.32	38
Oedemia nigra .....	mean 106.34	165
Clangula clangula americana .....	104.72	165
Goose (Sp?) .....	five individuals avg.	107.0
Goose, Domestic .....	106.7	147
Oie commune .....	106.7	38
Oie rieuse (Cackling Goose?) .....	109.4	38
Cygne à bec rouge .....	105.78	38
Prairie Falcon ♂ in December, immediately after being shot .....	106.6	78
Faucon .....	104.9	38
Hawk (Kestrel?) .....	avg. max. 108.32	167
Hawk (European Sparrow?) .....	avg. max. 107.3	167
Tiercelet .....	106.52	38
Autour .....	109.58	38
Western Red-tail Hawk, in August, alive .....	106.2	78
Swainson's Hawk ♀ alive, April 24 .....	106.6	78
American Rough-leg Hawk ♂ in December, after being shot .....	105.8	78
Osfraie .....	104.36	38
Gypaete .....	105.8	38
Globose Curassow ♀ alive, in captivity avg. 4-106.4		169
Globose Curassow ♂ alive, in captivity avg. 3-106.4		169
Gellinotte (Sp?) .....	108.95	38
Lagopede (Sp?) .....	106.88	38
Natal Francolin (Francolin natalensis), in captivity, 3:30 p. m. ....	107.9	97
Willow Grouse ♂ (taken in Arctic regions) .....	109.04	156
Prairie Fowl ♀ .....	109.4	156
Prairie Fowl ♂ .....	109.76	156

		Weight	Authority
Turkey	.....	109.0	156
Dindon	.....	108.86	38
Guinea Fowl	.....	110.0	156
Pintade	.....	111.02	38
Pheasant (Sp?)	.....	108.7	156
Ring-neck Pheasant ♂	avg. of two	107.5	109
Ring-neck Pheasant ♀	.....	106.0	108
Domestic Fowl ♀	avg. max.	107.3	167
Domestic Fowl	avg. of 111 individuals	106.9	156
Domestic Fowl ♀	.....	107.6	147
Domestic Fowl ♀	avg.	106.55	38
Domestic Fowl ♀ at large	avg. of three	104.6	109
Domestic Fowl, laying, and at large	.....	106.3	164
Domestic Fowl (Leghorn), laying hens	avg. 3	107.7	153
Domestic Fowl (Leghorn), laying hens, after exercise	.....	108.4	153
Domestic Fowl, lifted from perch at night	...	105.08	112
Domestic Fowl ♀ setting	avg. of two	103.6	109
Domestic Fowl, "setting, average of many"	..	105.6	108
Domestic Fowl, brooding by day	.....	107.06	112
Domestic Fowl, setting	.....	106.7	164
Domestic Fowl ♂	avg. max.	107.5	167
Coq	.....	avg. 103.46	38
Bantam ♀	avg. max.	107.8	167
Bantam, Leghorn, setting	.....	104.0	109
Bantam ♂	avg. max.	107.39	167
Paon	.....	107.15	38
Foulque	.....	104.9	38
Sun Bittern (Europygia helias) in captiv- ity, 3:30 P. M.	.....	102.4	97
Pluvier	.....	104.9	38
Hooded Dotterel—"One minute dead"	.....	107.0	153
Killdeer ♀ June, taken immediately after being shot	.....	106.6	78
Barge	.....	107.98	38
Chiornis minor (Sheathbill), taken in 1836 and 1837	.....	104.0	165
Stercoraire Pomer	.....	104.54	38
Le Cordonnier (Megalestris skua?)	mean	104.2	165
Rissa tridactyla	.....	106.6	165
Mouette tridactyla	.....	105.26	38
Mouette blanche	.....	104.18	38
Larus argentatus	.....	108.32	165
Goëland argenté	.....	108.14	38
Larus canus	.....	mean 107.1	165
Common Sea-gull, juv.	avg. max.	106.7	167
Larus fuscus	.....	mean 106.9	165
Goëland à manteau gris	.....	105.26	38

	Weight	Authority
Mouette gris.....	106.52	38
Gull (Sp?) .....	100.4	139
Uria grylle.....	mean 105.5	165
Uria troile.....	mean 104.5	165
Alca torda .....	mean 104.9	165
Guillemots .....	104.9	38
Pigeon, Domestic.....	avg. 107.87	38
Pigeon, Domestic.....	107.6	147
Pigeon, Domestic.....	108.0	156
Pigeon, Domestic.....	avg. 105.6	156
Pigeon, Domestic.....	107.24	156
Pigeon, Domestic ♀ .....	107.45	167
Pigeon, Domestic ♀ brooding, noon.....	104.0	78
Pigeon, Domestic ♂ .....	avg. max. 106.75	167
Speckled Pigeon ( <i>Columba phæonota</i> ), in captivity, 3:30 P.M.....	110.+	97
Mourning Dove, in captivity, with crippled wing, noon, Sept.....	106.2	78
Ruddy Quail ( <i>Geotrygon Montana</i> ).....	110.+	97
Road-runner ♂ taken 11 A. M. in October, immediately after being shot.....	107.4	78
White-crested Turaco ( <i>Turacus corythaix</i> ), in captivity, 3:30 P. M.....	104.2	97
Ara oratrix, in captivity, noon, Sept.....	102.6	78
Parroquet .....	105.98	38
Para Motmot ( <i>Motmotus paraensis</i> ) in cap- tivity, 3:30 P. M.....	104.1	97
Barn Owl.....	avg. max. 103.46	167
Long-eared Owl ♂ directly after being shot, 1 P. M., May 2.....	104.2	182
Long-eared Owl, taken alive, June, 2 P. M... 103.3	78	
Long-eared Owl ♀ directly after being shot, 1 P. M., May 2.....	103.4	182
Owl (Tawney?) .....	avg. max. 105.08	167
Owl (Tawney?) .....	avg. max. 106.0	167
Saw-whet Owl, in captivity, 3:30 P. M.....	104.3	97
Chat-huant .....	105.98	38
Owl (Horned?) .....	avg. max. 105.98	167
Owl (Horned?) .....	avg. max. 106.0	167
Choutte .....	106.52	38
Western Nighthawk, taken in daytime, July, after being shot.....	104.2	78
Swift (European?) .....	111.2	156
Western Hairy Woodpecker ♂ 3 P. M., August, after being shot.....	105.5	78
Downey Woodpecker, in captivity, 3:30 P. M. .....	108.3	97

		Weight	Authority
Williamson's Sapsucker ♀ alive, 4 P. M., April 24	108.2	78	
Red-headed Woodpecker ♀ 5 P. M., July, after being shot	107.2	78	
Ant-eating Woodpecker ♂ 3 P. M., October, after being shot	106.6	78	
Lewis Woodpecker ♂ 4 P. M., August, after being shot	107.0	78	
Western Flicker ♂ 5 P. M., August, after being shot	106.6	78	
Western Flicker ♀ taken alive Sept., 3 P. M.	106.4	78	
Passerine birds	107.6 to 111.2	112	
Hammond's Flycatcher ♂ noon, August, after being shot	106.2	78	
Grieve commune	109.4	38	
Thrush (Sp?)	avg. max. 108.86	167	
Thrush (Sp?)	109.0	156	
Fieldfare	110.6	156	
Redwing	109.9	156	
Song Thrush	avg. max. 108.2	167	
Catbird, 2 P. M., in June, immediately after being shot	106.4	78	
Curved-billed Thrasher ♂ 3 P. M., in October, directly after shot	107.4	78	
Water Ousle ♀ 3 P. M., in July, directly after shot	106.4	78	
Swallows (Sp?)	111.2	139	
Bohemian Waxwing ♀ alive, after struggling, 5 P. M., March 5	107.2	78	
Bohemian Waxwing ♀ directly after being shot, 5:30 P. M.	106.2	78	
Bohemian Waxwing ♀ directly after being shot, 5:00 P. M.	107.8	78	
Bohemian Waxwing ♂ directly after being shot, 5:00 P. M.	108.0	78	
Warblers (Sp?)	109.4	10	
Audubon's Warbler, 6 P. M., May 7	108.6	182	
White-rumped Shrike ♀ 4 P. M., August, directly after shot	108.4	78	
Rocky Mountain Nuthatch ♀ 1 P. M., August, directly after shot	107.0	78	
Great Titmouse	111.2	156	
Greater Bird of Paradise (Paradisea apoda) in captivity, 3 P. M.	106.7	97	
Magpie, juv., alive, 4 P. M., July. avg. of five	106.5	78	
Long-crested Jay, noon, July, directly after shot	108.4	78	

		Weight	Authority
Arizona Jay ♀ 4 P. M., October, directly after being shot.....	109.0	78	
Sooty Jay ( <i>Psilorhinus morio fuliginosa</i> ), in captivity, 3:30 P. M.....	110.+	97	
Jackdaw ♀ .....	avg. max. 108.86	167	
Jackdaw ♂ .....	avg. max. 108.4	167	
Choneas .....	107.78	38	
Corbeau (Raven or Crow?) .....	109.22	38	
Starlings .....	avg. max. 109.25	167	
Rocky Mountain Creeper ♀ 3 P. M., July, directly after shot.....	108.2	78	
Thick-bill Red-winged Blackbird ♀ 5 P. M., directly after shot.....	109.0	78	
Moineau .....	max. 112.1	38	
Moineau .....	min. 105.8	38	
Western Meadow Lark ♂ directly after being shot, March 4, noon.....	107.2	175	
Sparrows (Sp?) .....	avg. 109.0	10	
Bouvieul .....	107.96	38	
House Finch ♀ 5 P. M., alive.....	108.3	78	
House Finch ♂ directly after being shot, March 4, 10:30 A. M.....	106.0	175	
Pine Siskin ♂ 2 P. M., July, directly after shot .....	106.3	78	
Sparrow (Sp?, probably <i>P. domesticus</i> ) .....	107.8	156	
English Sparrow, avg. 11, alive, 4 P. M., July	108.3	78	
English Sparrow ♀ avg. 6, alive, August.....	108.0	78	
English Sparrow ♀ avg. 2, alive.....	108.1	78	
English Sparrow ♀ June 11th, directly after being shot.....	109.4	78	
English Sparrow ♂ alive, January 26th.....	109.0	78	
English Sparrow ♂ alive, August.....	107.8	78	
Chestnut-collared Longspur ♂ October, directly after shot.....	109.6	78	
Western Vesper Sparrow, 4 P. M., October, directly after shot.....	109.0	78	
Western Vesper Sparrow ♂ directly after shot, April 24, 5 P. M.....	108.6	78	
Bruant de niege.....	109.67	38	
Shufeldt's Junco ♂ directly after being shot, noon, January.....	107.50	175	
Cassin's Sparrow ♂ 2 P. M., July, directly after shot .....	108.0	78	
Spurred Towhee ♀ 1 P. M., July, directly after shot .....	108.0	78	
Lark Bunting, in captivity, 3 P. M.....	110.+	97	
Bruant .....	109.04	38	
Yellowhammer .....	109.8	156	

There are several conflicts in the published records on bird temperatures which are probably due to differences brought about by season, sex, struggling, and, too, in the early records, by imperfect instruments, for the modern accurate self-registering clinical thermometer was unknown to Milne-Edwards and his predecessors, its substitute being a crude affair, and such as it was, only just beginning to be used in physiological and clinical investigations.

Sutherland (112) concluded from his study of bird temperatures that "the result seems to show that the higher the bird in the zoological scale, the higher in general is the temperature of the blood"; in other words, as birds have risen in the zoological scale, their temperatures have become elevated *pari passu*. In general, this conclusion is substantiated by Table No. 6. If the writer is not in error, what occurs in the whole class Aves is also found more or less within the orders and families of the class—*i. e.*, differences of "highness," both in taxonomy and of temperatures, in orders and in families; if this be true, a steadily rising curve of the temperatures found in the class Aves would not only be unexpected but it would be suspicious.

What one would anticipate under these conditions is a more or less steadily rising curve, subject to undulations which are brought about by differences of temperature in the families of the orders involved; this anticipation is realized to a reasonable degree by the temperatures in Table No. 6, which show a distinct tendency to rise with the species, and be subject to undulation when the linear classification jumps from family to family. It seems to me that there is more than chance in the parallelism between the rising body temperature and the bird's elevation, despite the scanty data, and despite the probable errors in both the data and the classification.

Let us see if any other writers have been convinced of this relation; Pembrey (156) says, "those animals which are higher in the scale of evolution, such as birds and mammals, have a high temperature, which is fairly constant and independent of the temperature of the surrounding air."

Simpson (165) seemed surprised to find that different families of the same order exhibited different temperatures, saying, "even families of the same order appear to differ considerably in body temperature," which, rather than a surprising thing, is what ought to occur if Sutherland's law be correct and apply to orders and families as it seems to apply to the class. Simpson appears to have been familiar with Sutherland's conclusion, and after denying that there is a relation between the highness of a *mammal* and the elevation of its temperature, he says that "the same appears to be the case amongst Class Aves, above the Ratitæ." I take

it that he based this adverse conclusion on his own work, which included the "Turbinaires, Staganopodes, Pygopodes, and Longipennes," a group of families forming but a small per cent. of the Class, and also taking in birds largely of the lower levels. Furthermore, he based his conclusions (seemingly) on the mean of the temperatures of the species in the family, which seems untenable, if it be true (as he points out) that there are differences of temperature amongst the families of the orders, and the more untenable if the species within the family also show different temperatures. Simpson also based his conclusions on the average temperatures of the twenty-four-hour period, which I feel is not correct; unless I am much mistaken, man's normal temperature is regarded as the average of the highest in twenty-four hours, *i. e.*, that taken between noon and six in the afternoon, and such is the method I have utilized, when possible, in my consideration of this phase of this study. I am strongly of the opinion that graduations of temperature occur primarily in the class, secondarily in the order, and again in the family; what occurs in the whole avian tree is repeated in the secondary, tertiary, and even smaller branches.

Seeking to confirm these ideas on grounds other than those of these meagre records, one may justifiably ask, are there any other facts (or reasons) which can point to, or explain, the assumed co-existence of "high temperatures" in "high birds," and "low temperatures" in "low birds?"

It is not possible here to go extensively into the question of the physiology of animal heat, but it can be examined briefly at one or two points where it applies to the ideas now in hand. It has been shown (148) that, with all mammals investigated up to date, each animal can go through only a definite and fixed number of metabolic changes during its period of post-embryonic development, a contention based on the fact that *all* such mammals consume equal total numbers of calories per kilo of weight, from birth to maturity; there are further indications that this ratio may also obtain through the whole period of life. These facts mean that the large mammal, which *in general* lives longer than the smaller one, goes through its chain of metabolic changes slowly, taking a long time to do so, while a small mammal does the reverse, using up its metabolic-change quota (which is identical in both mammals) swiftly. The large mammal lives long and slowly, the small one briefly and swiftly, a difference in "swiftness of life." What is known as to a correlation between size and longevity in mammals tends to confirm this theory of the "swiftness of life," for in the scale of size represented by the elephant, camel, dog, and mouse, variations in size and longevity are found to go hand

in hand. Another way to put this view of the swiftness of life is that the rapidity of growth from birth to maturity is proportionate to the metabolic intensity, which last is, as said before, directly related to size; the elephant takes years to mature, the mouse can breed at the age of a few weeks. This difference in the speed of life process in large and smaller animals is not based on theory, but is demonstrable by experimental methods (156), all of which show that the metabolic intensity is proportionate to the animal surface area, which is relatively larger in the smaller mammals (148). Hand in hand with this slowness or swiftness of metabolic processes are found corresponding differences in the animal's physiology, particularly in the respiration, heart rate, temperature, and possibly in the *embryonic* metabolism. There are some indications at hand suggesting that this relation of swiftness of life and body size prevails in the embryonic, as well as in the post-embryonic stages of existence. There is suggestive evidence that the larger the mammal the longer is its gestation period: with the mouse it is three weeks and with the elephant at least eighteen months, and animals intermediate in size show a fairly well-defined intergrading in the gestation period length. Pembrey's remark that "the temperature of the smaller mammals and birds is often higher than that of the biggest" (156) gives a logical introduction to the question, Does this relation of size and swiftness of life in mammals obtain also with birds? Simpson (166) has definitely answered it in the affirmative, so far as the hen is concerned, for he stated that the large and most lethargic birds (*i. e.*, of hens) had a much lower temperature than the smaller and more active ones. I am convinced that a thorough study of avian physiology will show the same variation in the swiftness of life in this class as is demonstrated in mammals. It seems quite likely that increasingly intense metabolism and steady diminution in size of birds are related, and that the intense metabolism finds expression in many other ways in the function of birds. For example, I have found a house wren's respiration to be 160 per minute, and that of a house finch to be 100. Rapid respiration and fast heart rate are always (in health) co-existent; if one take the respiration: pulse rate index of man, *i. e.*, one to four, and apply it to these two species, it would show the wren to have a pulse of 640, and the finch, one of 400 beats per minute. Since there seems little known about a bird's minute physiology, it might be hazardous to assume that the human index can be correctly applied to birds. However, there can be no question as to the amazing rate of the heart beat in birds; if one hold an English sparrow or any small bird loosely but securely and gently in the hand, and apply it closely to one's ear, the bird's heart, as it

beats, sounds like the rapid tick of a small watch\*. All these observations merely point to the exceedingly intense metabolism and swiftness of physiologic processes in such small birds, a combination of conditions that should produce high body temperatures in small birds, and a brief study of Table No. 6, shows clearly that the birds with highest temperatures are, as a rule, the smallest of birds; moreover, it is held by physiologists (151) that the power to produce heat is proportionate to the activity or sluggishness of the animal (not specifying class). These facts again lead to a belief in the general correctness of Sutherland's law as to low and high temperatures in "low and high" birds. There are some relatively small birds which have low temperatures, as, for example, the apteryx. It seems to me that this is a good example where it is not size but the primitive character of the bird which determines the elevation of its temperature, but this is not proven; it may be a true exception, or the low record may be due to errors of observation. It is to be noticed that one record of a pigeon, the speckled pigeon, shows a very high temperature for a bird classed as relatively low; the whole of the facts in this, and similar cases, are not known, and compel again one's suspending *final* judgment pending further light.

In further support of the relation between elevation of temperature and taxonomic standing, it may be recalled that as birds have grown up, and away, from their proto-avian, or proto-reptilian ancestors, they have become better and better feathered, and feathers are said to have made birds what they are, the warmest-blooded creatures in existence, whence it follows that the farther they have traveled (without later recession) from their primitive ancestry, the more elevated have become their body temperatures. It seems to me that weight of evidence supports Sutherland's hypothesis, and for the purposes of this discussion it is held to be true.

Now, if one holds that birds' temperatures are more and more elevated as the species is higher and higher in its phylogeny, one may ask, does this condition have any influence on the length of incubation? It must here be remembered that it is possible that "swiftness of life" may embrace the embryonic period of birds as it seems to with mammals, and that the specific temperature and the incubation length are co-ordinate, assuming this to be true for the moment

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\*Since the above was written I have learned that Buchanan (174) has determined the heart rate in several bird species, using the electrocardiogram method for its detection. His results are almost incredible, and show most strikingly the wonderful metabolic activity of birds, especially the small species; Buchanan gives the heart rates as follows: Gold-finch 900 to 925 per minute, green-finches 700 to 848, sparrow 745 to 850, pigeon 141 to 225, hen 304 to 345.

on hypothetical grounds alone. Thus, this relation of metabolic intensity, size, and length of incubation may account for the loose relation known to exist between a bird's size and its incubation length, a relation admitted in the discussion on that theory. It seems to me that there is direct experimental evidence of the effect of differing temperatures on the incubation length; it has been shown that an *optimum temperature* is the most important of the three factors necessary to successful incubation, and that this optimum emanates from the incubating parent, and that with hens' eggs, their *usual minimum duration of incubation* can be *shortened a few hours* by carefully raising the temperature of the incubator a little above the usual optimum, which is identical under the hen and in incubator practice.

Until evidence is forthcoming to show that these two conditions do not apply to all other birds' eggs, it seems tenable to believe that as birds have slowly risen in evolutionary height, their temperatures have also been correspondingly elevated, and that these increasingly higher temperatures have gradually shortened the periods of incubation. What occurs with a hen's egg during one incubation period through a slight elevation of the incubator temperature, has taken place in lesser degrees, in nature, for countless bird generations; each increment of temperature elevation, however slight, added by each succeeding ascending generation, has correspondingly influenced the length of incubation, always resulting in some shortening. This process has been, probably, exceedingly slow, consuming ages in accumulating a patent change, both in the body temperature and in the incubation period yet, in the end, as we see it today, it has swept on with striking results, the Passeres having forged ahead, through their very high temperatures, to a fourteen-day period, while the ostrich and other birds with low temperatures are marooned at forty-two (or more) days. From the foregoing it seems, to me, impossible to escape the conviction that *the true length of incubation is fixed or determined by the temperature of the incubating parent*, long with low temperatures, and brief with high temperatures. Inasmuch as there is a goodly amount of support to Sutherland's law of low temperatures with "low" birds and higher temperatures with "high" birds, I would tentatively enunciate the idea that *the true length of incubation is determined by the bird's position in the avian scale of life*, basing this hypothetical law on the assumed relation of temperature elevation to incubation length, and of temperature elevation to the species' position in avian taxonomy.

If the various data collected together in this study are now to be examined and interpreted from the viewpoints

just enunciated, it becomes necessary to arrange the species affected, according to some reasonably acceptable classification. It was with hesitation that I approached this question of classification, and when the data finally *had* to be classified, I wrote to several of my professional ornithological friends, requesting their opinion as to the *best* present avian classification. All, as a unit, expressed themselves virtually in the words of one who said, "There is *no best* classification," saying further that the arrangement of avian taxonomy as given by Gadow, and slightly modified by Knowlton (10), was as good as any, which is the one followed in listing the incubation periods, and in the secondary tables and lists given in this study.

In speaking of a species "lowness" or "highness," I do not overlook the many difficulties attendant upon a determination of these levels. What I really would like to know, viewing the question from the standpoint of this discussion, is how far has a given species traveled from its proto-avian ancestors, and not how much has it specialized. No linear classification can show this, however perfect our knowledge may be, nor can it exhibit the true positions of species in one family in any given order as levelled with species in a family in another order, nor yet can it give an adequate idea of the relation of species of different families in the same order. Many inconsistencies and contradictions appearing under the present explanation of what controls the *true* length of incubation are possibly due, not only to lacunæ in our knowledge, and to errors in the records of incubation lengths, but also to the shortcomings of a linear classification. In other words, incorrect taxonomy, and the inability to properly depict the relation of species in one order to those in another, result in what appear to be severe dislocations of incubation lengths from positions one would assign to them under the present explanation.

Within natural groups (or families), the incubation lengths should be more or less characteristic because the members of such groups have diverged but little, *inter se*, and being less plastic than many other characters, the incubation length, under these circumstances, would diverge still less, resulting in a condition substantiating Evans' (2) first conclusion, to-wit, that natural groups (or families) have incubation periods more or less characteristic to such groups, a conclusion borne out by the incubation length data given in Table No. 1; the gradations in some families between the accepted taxonomic positions assigned to the species correspond surprisingly closely with the variations of incubation length of the same species, especially if in such families the largest species are ranked as lowest. If all families be so arranged, the undulating curve of incubation

lengths becomes still more striking in its trend upward as the species also trend upward.

Despite the difficulties inherent in a linear classification, and the errors and conflicts in the incubation records, these records show clearly that the incubation period becomes shorter as the species mount the avian tree; it is possible that a rearrangement of the species according to some other classification might alter the curves radically and make other interpretations necessary; it is equally possible that a rearrangement might strongly fortify the present conclusions. Time and space forbid trying other classifications or combinations. It is obvious that the list of incubation periods shows also that birds, in general, grow smaller as one follows their life scale upwards, a fact which accords with the suggestions as to "swiftness of life," size, and temperature. One must not overlook the possibility that the character of "swiftness of life" embraces the embryonic period (incubation) of life with birds, as it seems to do with the embryonic period (gestation) of mammals.

There is much to sustain the belief that the intensity of metabolism and the speed of embryonic development are correlated (155), but the details of this evidence cannot, however, be given here. That size and temperature are more or less correlated both with mammals and birds is unmistakable; that size, temperature, and taxonomic standing are all parallel is not so evident, yet it looks as though the lower birds are the larger ones, and that the tendency to become smaller and to have shorter incubation periods, as the avian tree expands upward, is fairly obvious. There is some geologic evidence pointing to the probability that ancient birds were generally larger, a fact well brought out by the large size of birds recently found in the California asphalt deposits; however, some living birds are small yet "low" in degree, *i. e.*, the kiwi, and some ancient birds were small yet close to the reptile in some ways, the ichthyonis, for example. This question of "lowness" or "highness" in birds, in the present discussion, is a question of how far has a given species journeyed away from its proto-avian stem, since it seems probable that the farther a bird is from its primitive ancestry, provided it does not later degenerate, the higher will be its temperature. I doubt very much that the present mainstays of taxonomy can alone measure this space between pro-bird and super-bird. I believe that future students of avian taxonomy will have to give more consideration, not only to embryology, but also to bird physiology, in order to correctly locate and plot the mile posts in a bird's taxonomic journey.

On the other hand, experimental evidence demonstrates that the usual length of incubation may be elongated by dif-

ferent bird temperature conditions, for it has been shown (162) that the eggs of the Egyptian goose hatch under a common hen in twenty-eight days, and under a muscovy duck in thirty days. One more suggestive contribution to the experimental evidence going to support the connection between temperature, size, and incubation length can be given here; Milne-Edwards (38) proved "that abnormal elevation of incubation temperature during the first period of incubation tends to diminish\* the size of the chick, and to produce dwarfs, though shortening the period."

If it be assumed that birds have in general grown smaller as they evolved upward, the question can be interpolated here (in fact, it can be considered the "acid test" of the truth of the assumption), have they benefited by their smaller size? It would seem so, since the efflorescence of the avian tree is made of the Passeres, practically all of which are very small. Perhaps the diminishing size of birds steadily accelerated their metabolic speed, which elevated the body temperature (or vice versa), and initiated a physiologic cycle, which is still revolving in ever diminishing circles.

If a rise of temperature in an artificial incubator can diminish the size of the chick, and shorten the incubation period, is it impossible to have the same thing happen in nature? Because one cannot see or measure the slight decrease in size, following an equally slight elevation of temperature in a given species, is it not, however, possible that thousands of such slight elevations of temperature, and of such minute reductions in size, can be cumulative, and end in results which are seen as existing conditions of today. It seems to me not only possible, but highly probable.

For the sake of convenience, I will term the explanation, (just elaborated), of factors fixing or controlling the *true* length of incubation "the temperature and ascent theory." A careful search through literature has disclosed but two hints that avian "lowness" or "highness" might have some effect on the incubation length. Both are more or less indirect, and the first is given in a few words by Fürbringer (102), who apparently considered this explanation, only to reject it by saying, "Thus the number of incubation days, which arranges itself more according to the size of the egg and bird, than to the relationship boundaries, can be of no great *taxonomic*\* significance," with which conclusion I cannot concur; the second is a suggestion made by Gadow (150), who held that the developmental period (embryonic plus nest life) stands in direct relation to the degree of "lowness" or "highness" of the bird, and that the "highest" birds

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\*Italics by W. H. B.

have the shortest incubation periods; so far as I am able to grasp Gadow's words, he correlated this shortness of incubation with no definite physiologic process, and spoke of it only incidentally in a discussion which related to the question of a bird's being precocious or altricial. Arrigoni (12) comes nearer to the final conclusion enunciated in this discussion, when he speaks of the length of the period of incubation as being related to the vitality (sic) of the bird. I am sure many others have grasped this idea, but I have been wholly unable to locate any written statements to such effect. These, then, are all the hints, direct or indirect, which suggest a possible relation of a bird's taxonomic standing to the length of its incubation period, that I have been able to discover in the ornithological literature at my command.

The evidence and data which I have been able to collect, point to the idea that the *true* length of incubation yields to change exceedingly slowly and with difficulty, much more so than characters of more recent acquirement, as color, size, etc. It is almost self-evident that the incubation periods of birds have been gradually shortened and that they are still slowly yielding, as in the past, to the influences outlined in the foregoing, and will continue to do so until this process of abbreviation becomes detrimental to the species. I am firmly convinced that, once a given period becomes shortened, it remains so, becoming longer again only *apparently*, and through such influences only, as slow or temporarily suspend the embryonic development, and returns, either in the next set of eggs, or with the first set of the next generation, to the previous normal, after the warping influence ceases. Once a species rises in "taxonomy," and has its temperature coincidentally elevated, which shortens its incubation period, this latter will remain constant under optimum conditions, even though the species later retrogrades morphologically. I believe that in this case, the bird remains physiologically stable, at the previous level, though its co-existing morphologic level will have been lowered, and that the bird will then have an incubation length which, under the present theory, would appear shorter than its morphology would predicate. On the contrary, a species may "specialize" morphologically, appear as "high," yet remain at the pristine lower physiologic level, and have, as a result, an incubation period longer than one would presuppose for it, judging from its morphology.

I am inclined to believe, as a result of this investigation alone, that there are physiologic as well as morphologic levels to be considered in taxonomy, and that these levels may differ in the same individual. I am convinced that there is a large and profitable field to be explored, in this question of the possible differences in physiologic and morphologic

levels of taxonomy. The length of incubation with the ostrich, and its temperature, would indicate for this species a higher physiologic level, taxonomically, than does its anatomy indicate for its morphologic level. It is higher physiologically than morphologically.

Whatever may be the final decision as to the relation of a bird's "lowness" or "highness" to its length of incubation, I am convinced that there will be but one conclusion as to the correlation of incubation temperature and the length of incubation, and that it is highly probable that, ultimately, the last word on this question will have to be said through determination of temperatures taken between the eggs and under the incubating parent (real or foster).

#### *Collateral Evidence*

Perhaps some additional light can be thrown on the theory in hand, through a review of the incubation conditions which prevail amongst birds' nearest relatives, the reptiles, and by a scrutiny of the effects of temperature on eggs other than those of birds and reptiles. H. Milne-Edwards (38) states that the period of incubation of silk-worm eggs can be prolonged to fifty days if subjected to low temperatures, that they hatch in thirty-four or thirty-six days if kept at a temperature of from 77° to 86° F., and in sixteen to eighteen days if they are maintained in a temperature of 86° to 95° F. Though it is true that these eggs belong to a creature in a class widely separated, and very divergent from the Class Aves, it is still quite suggestive that with them is found a high grade of elasticity in the length of incubation, which is governed by variations in the temperature conditions; this is mentioned to illustrate how potent an influence variations in temperature can have on embryonic development. The close relationship between reptiles and birds warrants a careful examination of the facts touching on incubation of reptile eggs; it is highly possible that the incubation of such eggs is subject to the same variety of control as those of birds, and that the same "temperature and ascent" theory applies as well to reptiles', as to birds' eggs. In line with this thought one may recall that the evolution of "parental care" shows a series of steps from low to high, broken it must be said, however, by striking exceptions; the evolution of parental care is well seen in reptiles and birds, taken as a whole, and has been said (155) to be associated "with the need of higher temperatures for development."

Reptile eggs, in all probability, have a normal minimum duration of incubation, which may be peculiar to each genus, *i. e.*, a specific incubation length; such eggs withstand successfully a much longer and some a far more severe chilling

spell than do those of birds, and they may bear, *relatively* higher temperatures, *i. e.*, the tuatara lizard's eggs 77° F. (126): they probably remain viable for far longer periods, their embryonic development persistently progresses at much lower temperatures than does that of birds, and one would predict, on these grounds, an exceedingly variable and elastic *apparent* length of *incubation*, which is borne out by the facts in the case. No reptile incubates its eggs, unless the devoted care given by the female python to its eggs can be so classed; this may, however, be a true but primitive kind of incubation, a real beginning in the scale of incubation habits, since it has been shown that a python's body temperature rises 10° F., above the surrounding air while covering its eggs, and Heilmann (118) says the temperature of a "quiet incubating snake" is about 50° to 53.6° F. If reptile eggs respond to the same controlling influences as do those of birds, it is possible that data on reptile incubation will disclose such correlation; I have discovered a few facts, which, while not nearly as numerous as might be desired, are nevertheless quite suggestive. If I read aright, it appears that the most primitive of all living reptiles is *Sphenodon punctatus*, and on grounds outlined in this discussion, its incubation period should be the longest of all living reptiles, *and it is*, lasting from twelve to thirteen months, reckoning from laying to hatching. It is necessary to recall, that about five months of this period, extend over the New Zealand winter, and that during this time the embryo ceases to develop, and hibernates in *ovo*, as it were, until the environmental conditions again become such that it can survive when hatched.\*

The next longest period of incubation amongst reptiles is that of the European tortoise (*Emys orbicularis*) which is probably a higher reptile than *Sphenodon*, though it is placed in an order ranked below that of the *Sphenodon*; in southern Europe the eggs of this tortoise hatch in five to six months, while in northern Russia (120), they require eleven months; a large part of this eleven months is the season of Russian winter, and during its intense cold, the developing tortoise embryo is in a condition of suspended animation yet, deducting this time from the whole period of incubation, the actual developmental period is still next to the longest amongst reptiles. Then comes the alligator, and in this instance one is on secure ground in having a

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\*It is possible that this reptile, which has persisted almost unchanged since the Lower Permian, survived because it was able to adjust, so to speak, its incubation to comparatively low temperatures, which may have supervened in the course of geologic changes, and which exterminated the then existing host of its huge contemporaries (dinosaurs, etc.), whose probable long incubation periods required an equally long period of relatively high temperatures.

record which has been checked frequently by eggs placed in an artificial incubator, where they require sixty days to hatch. The measuring of the true length of incubation amongst other reptiles becomes more and more perplexing as one takes up the succeeding ascending orders. It is exceedingly difficult to decide what is the true length of incubation with many snakes and lizards because of the ease with which the embryonic development of these animals can be slowed down, or temporarily suspended, and because of the high probability that the same reptile species may exhibit all gradations between complete oviparity and ovoviparity, gradations which can cause a difference of days or even weeks in the apparent length of incubation in the same species. This possibility also is mentioned here because it is probable that oviparity and ovoviparity are interchangeable according to environment, in certain other species.

This causes a wide variation in the records of incubation lengths of reptiles, and adds to the difficulty of reaching conclusions on the point now in mind, yet in spite of this and the paucity of records, it seems to me that reptiles also exhibit a tendency to shorter incubation periods as the species is higher in its scale of life, which tendency seems to show in the data given in Table No. 7.

TABLE NO. 7  
*Incubation Periods of Reptiles*

	Period	Authority
Green Turtles.....	8½ weeks	119
Loggerhead Turtles.....	8½ weeks	119
European Tortoise.....	20 to 44 weeks	120
Tuatara Lizard.....	52 weeks	121
Crocodile .....	12 weeks	120
Alligator (in incubator).....	8½ weeks	122
Common Swift.....	6 to 8 weeks	123
Python reticulatus.....	6 to 8 weeks	125
Python molurus.....	10 weeks	120
Black Snake.....	8½ weeks	123
Fox Snake.....	7 3/7 to 8 6/7 weeks	123
Corn Snake.....	6 to 8 weeks	123
Yellow Rat-snake.....	11 weeks	123
Ring Snake.....	5 6/7 weeks	123
Milk Snake.....	8 1/7 weeks	123
King Snake.....	6 to 8 weeks	123
Coral Snake.....	8 2/7 to 8 4/7 weeks	123

If reptile eggs vary in incubation lengths according to the applied temperatures, it is proper to ask if there be any evidence in the temperature of reptiles, showing trends similar to those in birds; reptiles are said to be "cold-blooded," but it can be shown that this term is only relative. The average

temperature of reptiles with weak respiration is  $1.8^{\circ}$  to  $5.4^{\circ}$  F. above the circumambient medium, and for others the following degrees have been given:

	Temperature	Authority
Turtles .....	$33.6^{\circ}$ F.	38
Chameleon .....	$1.8^{\circ}$ F. (above air)	38
Lizards .....	$1.3^{\circ}$ to $14.6^{\circ}$ F. (above air)	38
Vipers .....	$4^{\circ}$ to $11.3^{\circ}$ F. (above air)	38
Boa (incubating) .....	$10.8^{\circ}$ F. (above air)	38
Snake (incubating) .....	$50.0^{\circ}$ to $53.6^{\circ}$ F.	118
Viper .....	$68.0^{\circ}$ F. (air being $58.0^{\circ}$ F.)	156
Python .....	$76.0^{\circ}$ F. (air being $60.0^{\circ}$ F.)	156
Turtle .....	$84.0^{\circ}$ F. (air being $79.0^{\circ}$ F.)	156

The fact that the male boa, which does not incubate, has a lower temperature than the female (156) is worth noting.

There is shown in the figures just given (see Table No. 7) enough tendency for the temperatures to rise as the species gets "higher" in its life scale to give color to the possibility that with reptiles, as with birds, the temperatures and the species become elevated concomitantly. From the "swiftness of life" point of view, it is interesting, and perhaps important, to note that the quiet, sluggish reptiles have lower temperatures than do the active ones.

A relationship between reptiles and birds, should, and does, leave in both, traces of a common ancestry; can one find indications of this in the incubation periods of birds? If the length of incubation in birds be, as I am convinced it is, a deep-rooted, inelastic and inherited characteristic, it should exhibit some proto-reptile or some proto-reptile-bird peculiarity or peculiarities; the data show, both with birds and reptiles a decided tendency to arrange themselves in groups of periods having a septenate multiple, *i. e.*, 14, 21, 28, 42 and 56 days. This septenate tendency has been explained on the hypothesis that it is an inheritance from ancestors which were aquatic, and subject to, and probably modified by, maximal tides every twenty-eight days. If this be true, it would bespeak an amazing tenacity in the persistence in birds, of this very ancient character. It may not, however, be a correct explanation, because the same septenate or monthly spacings are to be found attached to the functions of mammals, *i. e.*, gestation and rut. It does not seem possible that such an old influence should have left an impress which is visible in a stem so far removed from the main trunk as is that of the mammal branch.

#### *Taxonomy, the "Ascent Theory" and the Data*

I know full well that real and apparent inconsistencies and conflicts will be found in the correlation of these three,

when the present data are viewed from several different points. Some come promptly to mind: according to modern taxonomists, the megapodes are near relatives of the domestic hen, and they should have, by this token, a length of incubation somewhat similar to that of the hen, yet it is in reality much longer, and far longer than one would predict, from my point of view, with birds of the comparatively high standing of the megapodes. Hence their incubation length does not seem to fit in with this "ascent theory;" how it fits in with the temperature side of the present explanation I do not know, as I have no temperature records of these queer birds. What are the possibilities in the premise? These birds may upset the whole argument, or they may be one of a few exceptions, or there are two other possibilities. It has been maintained in this discussion that the true length of incubation is fixed by the *parent's temperature as applied to the eggs*; thus this method of fixing cannot apply to the megapodes because their eggs are hatched, not by heat supplied by the parent bird, but by that arising in the decaying mound, its temperature being given as 95.0 to 96.0 F. (131), which are the lowest successful incubation temperatures, for birds' eggs, known to me. It might be assumed, in the first place, that the mound incubation habit is very ancient, dating from the time when the megapodial ancestors were much less removed from the pro-bird than at present, and that the ancestral species had at that time, a comparatively low temperature, approximating that of the present incubation mound. If the mound building habit arose at that time, and continued to the present, it would explain the inappropriately long incubation because, on this last assumption, it has not varied during all the past ages, notwithstanding that in the *interim* there have been great change and variation in the morphology of the group. The eggs have, during all this time, been hatched by a temperature which has varied little, if at all, resulting in an unchanging incubation length. On the contrary, it is possible that this mound incubation habit is of recent origin, and that the present recorded megapod length of incubation is an apparent one only, being the true length plus X days of slowing down of embryonic development caused by the low temperature of the mound; it is difficult to picture just how, under this suggestion, the eggs successfully became adapted to such abnormal prolongation of incubation. This might be tested experimentally by subjecting megapode eggs to varying temperatures in artificial incubators; it also would give an added light if one knew what is the true length of incubation of the genus *Maleo*, since eggs of this genus are said to be incubated, not in mounds, but by the sun's heat or by hot springs. The case of the megapodes falls without the confines of my

present theory, as regards taxonomic standing, but within the control of the temperature explanation. The incubation length of the flicker, not a very high, or a small bird, is given as eleven to twelve days, which seems unduly brief in the light of this study. This short period (*if it is correctly estimated*) may be due to temperature conditions, since this species nests in tree holes, where there is little heat loss, and lays a large complement of eggs, which, as they develop, would tend to higher and higher temperatures as the embryos grow. With other hole-nesting species laying few eggs, this latter effect is not present, an absence which may help to account for longer incubations with these species.

What has happened in the case of parasitic cowbirds and cuckoos since their eggs are incubated by foster parents? An answer to this problem will only be had when the temperatures of the parasitic birds and of their dupes are known, as well as the temperatures of such cuckoos and cowbirds given to autogenous incubating. It is not too late to learn the last, as there are still some of the species of these genera which incubate their own eggs. In the development of this parasitic habit, it undoubtedly was at first a "hit or miss" arrangement; if the parasitic eggs were given too high heating by the foster parents, their embryos died, and the reverse could also be true, though an incubating temperature slightly below the optimum might result in a successful, but prolonged, incubation. Such a "hit or miss" method, after repeated trials through a long stretch of time, together with a possible tendency of the female cowbird to return, when mature, to a nest similar to that in which it was raised, would eventuate in a variety of selection, which would secure a large percentage of successful incubations. The cuckoo is said (110) to lay eggs which are, proportionately to itself, the smallest of all birds' eggs; has this arisen because of the possibly higher temperatures of the foster parents?

What happens when a quail's egg is hatched by a bantam hen, or what would happen if a magpie's eggs were placed under a bantam?

It seems difficult to reconcile a mourning dove's incubation period, which is said to be fourteen days, with that of the robin's of equal length, because taxonomists are agreed that the latter is a much higher bird; perhaps both of these species have traveled, physiologically, equally far from the pro-avis ancestor, but along quite divergent roads. The ostrich is regarded, by most classifiers, as lower than the emu, yet its incubation period is not as long as that of the latter. This example may not be a real conflict with the present "ascent theory," but the lack of concord may be due to an error in taxonomy, because at least one ornithologist

(120) believes that the emu is a lower and a more primitive bird than the ostrich, and his classification is supported by the position taken in this paper, *i. e.*, that the longer is the incubation period, the lower is the bird. The secretary bird is believed to be a primitive survival, not greatly changed, from its pro-hawk-heron ancestor: if this be correct, a long incubation period would be predicted, viewed from the "ascent theory," a period as long, or longer, than all of its near relatives, and such is the case (barring one or two questionable exceptions). These and similar questions must be decided by experimental work; they are but a few of the many fascinating ones uncovered by a study of the length of incubation.

It is possible that many conflicts, and inconsistencies in this new theory, will be cleared up when the present incubation records are checked and corrected by new observations, undertaken to eliminate, or allow for, the conditions which *apparently* increase or decrease the *true* length of incubation, and when a method of recording avian classification will have been devised which does *not* project the vision of the mind's eye along a single line, and which will graphically portray the relation of genera to genera, irrespective of family, or order. Perhaps such a three-dimension demonstration scheme is impossible of attainment.

The chances of any given explanation being correct are larger if the results it foreshadows can be shown to be beneficial: if the bird's taxonomic position, temperature, size, and length of incubation be correlated, it is pertinent to ask, has the combination been beneficial to the race? It would seem so, judging from actual experience in nature, since so large a number of existing species are of the highest levels, have diminished in size, have acquired short incubation periods, have developed high temperatures and have concomitantly flourished and multiplied. Do short incubation periods prove helpful to the species? Is there any advantage to the robin that it gets its young out of the nest and able, more or less, to shift for themselves in four weeks from the laying of the eggs, while a goose, a turkey, or a red-tail hawk, in the same time is able to complete only the embryonic development of its young, and has still ahead of it, the long post-embryonic period of development, and all the care incidental to it, plus such post-nidicular time, during which it must give more or less care to its young? Is there any benefit to a species to be able to put two broods of young into the field, while another species can, in the same time, put but one? It seems to me that these questions can be answered only in the affirmative. If it be true that the number of eggs laid in a set is in direct ratio to the dangers encountered by the species (110), it also would seem reasonable

to believe that a species would be better able to successfully maintain its status in the face of its daily dangers, through the increased prolificity made possible by the short incubation period permitting more, and perhaps equally large broods to mature during the breeding season; this is but another way of making the eggs proportionate to the dangers meeting the species in its daily life, and may be looked upon as a result of the higher birds having high temperatures.

More broods each season inflict greater responsibility and labor on the parents; this affects but two, while the greater multiplication of individuals certainly more than counterbalances this. As said above, Gadow holds that the shortened incubation period, and its correlated long nest period (?) reflects benefits on both parents and young; I believe it does help the young, but as to the parents, I am inclined to feel that for them, the beneficial effects are negated by the disadvantage of more labor, wear and tear, etc. In all other creatures, the parent is so universally disregarded, so to speak, for the good of the young, that I am skeptical as to there being an exception with birds. The question also arises of two species, which young are better able to fend for themselves at the end of a given time, viewing the question from the standpoint of the possible beneficial or injurious effects of a short or a long incubation period, those hatched after a short or those after a long incubation? Two months after hatching are young robins, or young quail, better able to shift for themselves, and to meet and overcome the perils of their daily life? It seems to me that the advantage lies with the higher bird, because of its shorter incubation period, which supports the belief that the diminishing lengths of incubation delivers benefit to the species. It is self-evident that such a continual shortening of the incubation period as I have assumed to have been in progress in the past, and which is probably still going on, may have for a given species advantages and disadvantages which cannot now be clearly apprehended since some may be disappearing and others only just coming into effect.

If my contention be correct, that the *true* length of incubation is a fixed and persistently inherited characteristic, and determined by the bird's temperature, and its position in its scale of life, it then becomes possible that this characteristic will be useful as an aid in allocating the correct taxonomic position of a species, taking a place (perhaps a very minor one) with anatomy, embryology, splanchnology, ptilosis, etc.; it seems to me that there are larger possibilities for usefulness in these directions for this character, than there are for such an unmeasurable and indeterminate char-

acter as the nervous system, which last has been used to place the Corvidæ at the apex of the avian tree. If this "temperature and ascent theory" of the control of the length of incubation, with birds, be correct, it will, at least, bring about a semblance of order where before more or less confusion prevailed; if it be fallacious, and untenable, then I can at least hope that this discussion may point out the lines of investigation along which, in the future, ornithologists will have to work in order to solve what in the past has been an unanswered riddle.

Correct or incorrect this discussion may, I hope, draw attention to the importance of gathering accurate data on the true length of incubation with birds, and its relation to their physiology and taxonomy.

It appears to me that some of the previous explanations as to what fixes, determines, or controls the length of avian incubation have held more or less of the truth, because they concern conditions which are effects of a single underlying cause, but I believe that there is no experimental evidence whatsoever, that differences in the size of bird, age of female, longevity of the parents, condition of the young at hatching, the size of the egg, or its shell, or the yolk size, or various telluric conditions ever *permanently* alter the *true* length of incubation; there is abundant experimental evidence (both accidental and intentional) that variations in temperature can prolong the time of incubation, and can shorten it to a slight extent, and presumptive evidence that this effect of variation in temperature in shortening the length of incubation, does in the end bring about the large variety of incubation lengths found with birds today.

#### *Data Needed for Further Study of This Problem*

The prosecution of this study has uncovered a lamentable dearth of information in many phases of the questions at issue, and in now calling attention to a few of these deplorably incomplete chapters of ornithology. I would remind ornithologists that in them they will find openings which will lead to splendid opportunities for original research in almost unexplored and unexploited fields, fields which may soon be swept out of existence before the devastating march of civilization. Data needed:

Exact length of incubation period of birds and reptiles,

Exact length of incubation of birds in polar and tropical regions,

The period of viability of birds' eggs,

The weights of birds, preferably of the breeding female,

The weights of birds' eggs,

The effects of superheating on birds' and reptiles' eggs,

The optimum incubation temperatures of birds' and reptiles' eggs,

Bird temperatures,

Temperatures under the incubating bird,

Reptile temperatures,

Minutiae of bird physiology.

### *Conclusions*

While final judgment and decision must be suspended on many, if not all, of the points at issue in this discussion, suspended at least until a much larger, and perhaps an entirely rewritten accumulation of data on all of the above questions has been made, I feel justified, at this time, in drawing the following *tentative* conclusions:

**Minor:** That

Our present incubation records include the *true* and the *apparent* lengths, the latter in the majority, probably,

The *true length* of incubation can be shortened (artificially) with extreme difficulty, but prolonged with ease,

The *true length* of incubation is loosely related to the size of the species, and still more loosely to the size of the egg,

There is little or no relation between the *true length* of incubation and precocity,

There is no relation between the *true length* of incubation and the longevity of the species, nor between it and the body-weight: egg-weight index,

There is no relation between the *true length* of incubation and the age of the female, or the size of the egg yolk,

Condition of the parents, faithfulness of the parents while incubating, viability of the egg, thickness of the egg shell, and influences listed under the head of "Telluric Conditions," have no lasting effect on the *true length* of incubation; when any of these conditions seem to modify the incubation length, it is merely an action of slowing the embryonic development, and causes no *permanent* change in the length of the incubation period.

**Major:** That

There is a *true or specific length of incubation*,

The *true or specific length of incubation* is a deep-seated, inelastic, and persistently unchanging (in human time measures) character,

Bird temperatures are closely related to the taxonomic "lowness" or "highness" of the species;

A bird's temperature determines, or fixes, the *true length of its incubation period*, and that only an abiding change in

the bird's temperature can *permanently* alter the *true* length of its incubation period,

Whence I would suggest the following

*Hypothetical Law,*

That the *true* or *specific* length of incubation is fixed by the "lowness" or "highness" of the species, particularly by the physiologic "lowness" or "highness," both of which are fixed by the distance the species has traveled (without re-treating) from its proto-avian ancestor.

TABLE NO. 1  
*Incubation Periods\**

Family—Species		Period Authority
Struthionidae		
Struthio Camelus—Ostrich	36 to 40 days	1
Struthio Camelus—Ostrich	45 to 48 days	9
Struzzo	50 to 60 days	12
Ostrich	50 to 60 days	11
Ostrich	42 to 49 days	10
Ostrich	42 days	7
Ostrich	42 days	8
Ostrich (In incubator)	42 days	6
Rheidae		
Rhea Americana—Common Rhea	35 days	1
Rhea Americana—Nandu	39 days	9
Rhea Americana—Great-billed Rhea	6 weeks	94
Rhea darwinii—Darwin's Rhea	30 to 31 days	13
Dromaeidae		
Dromaeus novae-hollandiae—Emu	56 days	1
Dromaeus novae-hollandiae—Emu	about 8 weeks	10
Dromaeus novae-hollandiae—Emu	58 days	9
Dromaeus novae-hollandiae—Emu	about 8 weeks	14
Dromaeus novae-hollandiae—Emu (under hen)	7 weeks	17
Dromaeus novae-hollandiae—Emu (Under normal parents ♀ & ♂)	57 days	17
Dromaeus novae-hollandiae—Emu (Under normal parents ♀ only)	63 days	17
Emu	50 days	15
Emu	58 days	94
Dromaeidae	"the period being 80 days"	16
Dromaeidae	70 to 80 days	25
Casuariidae		
Casuarius bennetti—New Britain Cassowary—(Mooruk)	42 days	1

\*The author is confident that some of the incubation-length records included in this list are grossly incorrect, yet they are incorporated in the data, with a feeling that they will, in the future, be more accurately determined, and in that form recorded, and thus be corrected.

Family—Species		Period Authority
<i>Casuarius australis</i> —Cassowary.....		
.....“probably 7 weeks or over”	14	
<i>Casuarius galeatus</i> (?)—Cassowary.....	9 weeks	1
<i>Cassowarie</i> .....	52 days	117
<b>Crypturidae</b>		
<i>Rhynchosotus rufescens</i> —Tinamou.....	21 days	1
<b>Apterygidae</b>		
<i>Apteryx australis</i> —Kiwi.....	6 weeks	1
<b>Spheniscidae</b>		
<i>Aptenodytes Fosteri</i> —Emperor Penguin		
.....“some 7 or 8 weeks”	20	
<i>Emperor Penguin</i> .....	7 weeks	138
<i>Aptenodytes Pennanti</i> —King Penguin....		
.....“said to be 7 weeks”	93	
<i>Pygoscelis Adaliae</i> —Adele Penguin.....	37 days	20
<i>Pygoscelis Adaliae</i> —Adele Penguin.....		
(more accurate).....	34 days	20
<i>Pygoscelis Adaliae</i> —Adele Penguin.....	31 days	20
<i>Adelie Penguin</i> .....	33 to 36 days	133
<i>Johnny Penguin</i> .....	33 to 37 days	134
<i>Eudyptes Chrysocome</i> —Tufted Penguin		
.....about 6 weeks	14	
<i>Catarrhactes chrysocome</i> —Crested Penguin		
.....about 6 weeks	1	
<i>Sphenicus demersus</i> —Black-footed Pen- guin .....	56 days	94
<b>Gavidae</b>		
<i>Gavia immer</i> —Loon.....	“about a month”	19
<i>Gavia immer</i> —Loon.....	29 days	3
<i>Columbus arcticus</i> —Black-throated Diver	28 days	1
<b>Podicipedidae</b>		
<i>Western Grebe</i> .....	21 days	18
<i>Podicipes nigricollis</i> —Eared Grebe.....	about 24 days	1
<i>Podicipes Minor</i> —Little Grebe.....	20 or 21 days	1
<i>Podicipes Cristatus</i> —Great-crested Grebe		
.....	21 to 24 days	1
<i>Podicipes novae-hollandiae</i> —Black- throated Grebe.....	23 days	17
<i>Podilymbus podiceps</i> —Pied-bill Grebe...		
.....	21 (?) days	3
<b>Diomedeidae</b>		
<i>Diomedea exulans</i> —Wandering Albatross		
.....“about 3 months”	14	
<i>Diomedea melanophrys</i> —Black-eyebrowed Albatross .....	60 days	1
<i>Diomedea melanophrys</i> —Black-eyebrowed Albatross .....	“about 60 days”	14
<i>Turbinares</i> (?) .....	35 days	25

Family—Species	Period	Authority
<b>Procellariidae</b>		
<i>Fulmarus glacialis</i> —Fulmar.....	“about a month”	1
<i>Fulmarus glacialis</i> —Fulmar.....	50 to 60 days	12
<i>Puffinus tenuirostris</i> —Short-tailed Petrel (Mutton Bird) .....	56 days	14
<i>Procellaria pelagica</i> —Storm Petrel.....	24 to 25 days	1
<i>Procellaria pelagica</i> —Uccello del tempeste	36 days	12
Storm Petrel (in incubator).....	35 days	2
<i>Oceanodroma leucorhoa</i> —Leache’s Petrel .....	30 (?) days	3
<b>Phaëthontidae</b>		
<i>Phaëthon americanus</i> —Yellow-billed Tropic ic Bird .....	28 days	3
Yellow-billed Tropic Bird..... (at least)	28 days	26
Yellow-billed Tropic Bird (in incubator).....	28 days	27
<b>Pelecanidae</b>		
<i>Pelecanus erythrorhynchos</i> —White Pele- can .....	29 to 30 days	3
White Pelican .....	29 days	30
<i>Pelecanus onocrotalus</i> —Pelikan.....	36 to 38 days	9
<i>Pelecanus occidentalis</i> —Brown Pelican.....	28 days	3
Pelican .....	“said to be 49 days”	28
Pelican (Sp?).....	30 days	1
<b>Phalacrocoracidae</b>		
<i>Phalacrocorax carbo</i> —Cormorant.....	28 to 29 days	1
<i>Phalacrocorax carbo</i> —Kormoran.....	28 days	9
<i>Phalacrocorax pelagicus pelagicus</i> —Pela- gic Cormorant (Est. by W.H.B.).....	26 days	21
<i>Phalacrocorax urile</i> —Red-faced Cormo- rant .....	21 days	3
<i>Phalacrocorax</i> Sp.?—Cormorant.....	28 days	28
<b>Sulidae</b>		
<i>Sula piscator</i> —Red-legged Gannet.....	45 days	14
<i>Sula bassana</i> —Gannet.....	39 days	3
<i>Sula bassana</i> —Gannet.....	39 days	1
Gannet (38 to 44 days).....	usual is 42 days	28
Gannets .....	39 days	25
<i>Sula serrator</i> —Australian Sula .....	“supposed to last only 33 days”	29
Gannet .....	“about 33 days”	14
<b>Ardeidae</b>		
<i>Botaurus lentiginosus</i> —Bittern.....	28 days	3
American Bittern.....	(at least) 4 weeks	39
<i>Ixobrychus exilis</i> —Least Bittern.....	(estimated) 17 days	40
<i>Botaurus stellaris</i> —Bittern.....	23 days	1
<i>Ardetta Minuta</i> —Little Bittern.....	16 or 17 days	1

Family—Species		Period	Authority
Ardea occidentalis—Great White Heron	.....	"about 30 days"	1
Ardea herodias herodias—Great Blue Heron	.....	28 days	3
Great Blue Heron.....	.....	"about 28 days"	41
Ardea Cinerea—Fishreiher.....	.....	25-28 days	9
Ardea Cinerea—Heron.....	.....	25 to 26 days	1
Herodias garzetta—Seidenreiher.....	.....	23 days	9
Herodias timoriensis—Egret.....	.....	about 4 weeks	14
Herodias timoriensis—White Heron.....	.....	4 weeks	42
Ardea ludoviciana—Louisiana Heron.....	.....	21 days	1
Butorides virescens virescens — Green Heron	.....	17 days	3
Green Heron.....	.....	about 16 days	43
Nycticorax nycticorax naevius—Black-crowned Night Heron.....	.....	24 (?) days	3
Nycticorax nycticorax—Nachtreiher.....	.....	21 days	9
Circoniidae			
Cirronia Alba—White Stork.....	.....	23 days	1
Cirronia cirronia—Weisser Storch.....	.....	32 to 38 days	9
Ibididae			
Ibis Aethiopica—Sacred Ibis.....	.....	about 21 days	1
Ibis molucca—Australische Ibis.....	.....	24 days	162
Guara alba—White Ibis.....	.....	21 days	3
Guara alba—White Ibis.....	.....	20-23 days	107
Carpibis spinicollis—Stachelibis.....	.....	22 days	162
Plegadis falcinellus—Sichler. (Bay Ibis)	.....	21-22 days	9
Plegadis autumnalis—Glossy Ibis.....	.....	21 days	3
Phoenicopteridae			
Phoenicopterus ruber—Flamingo.....	.....	28 days	193
Phoenicopterus Sp.?—Flamingo.....	.....	30 to 32 days	1
Palamedeidae			
Chauna chavaria — Tschajia (Derbian Screamer) .....	.....	42 days	9
Anatidae			
Mergus americanus—American Merganser	.....	(at least) 28 days	31
Mergus americanus—Merganser.....	.....	28 days	3
Mergus merganser—Goosander.....	.....	28 days	1
Mergus serrator—Red-breasted Merganser	.....	26 to 28 days	1
Red-breasted Merganser (under hen).....	.....	"about 4 weeks"	32
Mergus serrator—Red-breasted Merganser	.....	26 to 29 days	3
Mergus cucullatus—Hooded Merganser.....	.....	31 days	1

Family—Species	Period	Authority
Fulvous Tree Duck.....	26-28 days	95
Tree Duck.....	26-28 days	95
Dendrocygna Fulva—Gelbe Baumente.....	32 days	162
Chenonette jubata—Hahnen Gans.....	28-29 days	162
Casarca casarca—Rote Kasarka.....	29 days	162
Anas platyrhynchos—Mallard.....	26 to 28 days	3
Mallard (varies from 23 to 29).....	27 to 28 days	95
Anas boscas—Wild Duck.....	26 days	1
Ducks .....	28 days	25
Anas domesticus—Domestic Duck.....	27 and 28 days	1
Duck .....	28 days	8
Duck—Common .....	28 days	33
Ducks .....	26 days	34
Duck—Common .....	24-29 days	9
Anas Rubripes—Black Duck.....	26-28 days	3
Black Duck.....	26-27 days	95
Anas angustirostris—Marbled Duck.....	25 to 27 days	1
Barbary Duck.....	30 days	33
Gadwell .....	28 days	95
Polionetta poecilorhyncha — Flecken- schnablente .....	about 29 days	162
Chaulelasmus streperus—Schnatterente.....	.....26 days	162
Anas superciliosa—Australische Wildente .....	.....27-28 days	162
Mareca Penelope—Widgeon.....	24 to 25 days	1
Mareca penelope—Pfeifente.....	22-23 days	162
European Widgeon.....	24 days	95
Querquedula crecca—Common Teal.....	22 days	1
Green-winged Teal.....	21 to 23 days	95
Blue-winged Teal.....	21 to 23 days	95
Cinnamon Teal.....	21 to 23 days	95
Querquedula cyanoptera—Blauflügelente..	.....26 days	162
Querquedula circia—Garganey .....	21 or 22 days	1
Querquedula querquedula—Knakente.....	.....about 24 days	162
Spatula clypeata—Shoveller.....	28 days	1
Shoveller .....	22 to 24 days	95
Dafila acuta—Pintail.....	22 or 23 days	1
Aix sponsa—Wood Duck.....	25 days	1
Wood Duck.....	28-30 days	95
Lampronessa sponsa—Brautente.....	31 days	162
Aix galericulata—Mandarin Duck.....	30 days	95
Mandarin Duck.....	28-30 days	1
Redhead .....	28 days	95
Nyroca ferruginea—White-eyed Duck.....	.....22 to 23 days	1

Family—Species	Period	Authority
<i>Nyroca nyroca</i> —Moorente.....	28 days	162
<i>Fuligula cristata</i> —Tufted Duck.....	22 to 23 days	1
<i>Fuligula fuligula</i> —Rheierente.....	25 to 26 days	162
<i>Metopiana peposaca</i> —Peposacaente.....	27 to 28 days	162
<i>Netta rufina</i> —Kolbenente.....	28 days	162
<i>Somateria mollissima</i> —Eider Duck.....	28 days	1
<i>Somateria mollissima borealis</i> —Northern Eider .....	36 (?) days	3
<i>Somateria mollissima borealis</i> —Northern Eider .....	25-26 days	137
<i>Somateria dresseri</i> dresseri—American Eider .....	25-26 days	137
<i>Somateria spectabilis</i> —King Eider.....	25-26 days	137
<i>Cereopsis novae-hollandiae</i> — <i>Cereopsis Goose</i> .....	35 days	1
<i>Cereopsis novae-hollandiae</i> — <i>Cereopsis Goose</i> .....	about 30 days	97
<i>Cereopsis novae-hollandiae</i> —Hühnergans... <td>30 days</td> <td>162</td>	30 days	162
<i>Anser cinereus</i> —Grey-lag Goose.....	28 days	1
<i>Anser domesticus</i> —Domestic Goose.....	30 days	1
<i>Goose</i> .....	30 days	8
<i>Geese</i> .....	30 days	34
<i>Goose</i> .....	30 days	33
<i>Geese</i> .....	28-29 days	9
<i>Anser brachyrhynchus</i> —Pink-footed Goose	28 days	1
<i>Anser arvensis</i> —Acker Gans.....	28-29 days	162
<i>Chen hyperboreus</i> —Schneegans.....	28-29 days	162
<i>Branta canadensis canadensis</i> —Canada Goose .....	28 to 30 days	3
<i>Bernicla canadensis</i> —Canada Goose.....	28 to 29 days	1
<i>Canada Goose</i> .....	17 days	35
<i>Canada Goose</i> .....	28-30 days	97
<i>Bernicla poliocephala</i> — Ashey-headed Goose .....	30 days	1
<i>Bernicla sandvicensis</i> —Sandwich Island Goose .....	31 days	1
<i>Chloephaga magellanica</i> —Magellangans.....	28-29 days	162
<i>Philacte canagica</i> —Emperor Goose.....	24 days	163
<i>Chenalopex aegyptiaca</i> —Egyptian Goose .....	27 to 28 days	1
<i>Alopochen aegypticus</i> —Nilgans, under hen (domestic) .....	28 days	162
<i>Alopochen aegypticus</i> —Nilgans, under Muscovy Duck .....	30 days	162
<i>Tadorna cornuta</i> —Shelldrake (common) .....	30 days	1
<i>Tadorna casarca</i> —Ruddy Shelldrake.....	30 days	1
<i>Pairina moschata</i> —Turkenente.....	35 days	162

Family—Species	Period	Authority
Olor cygnus—Whooping Swan.....	35 to 40 days	3
Cygnus musicus—Whooper.....	35 days	1
Cygnus olor—Mute Swan.....	35 days	1
Cygnus olor—Swan.....	35 to 42 days	36
Cygnus Melanocoryphus — Schwartzhals schwann .....	35 days	162
Schwäne (Cygnus) .....	35 days	9
Swan .....	35 to 40 days	25
Swan .....	"between 5 and 6 weeks"	25
Swan .....	42 days	8
Cygnus nigricollis—Black-necked Swan..	35 days	1
Cygnus atratus—Black Swan.....	35 days	1
Chenopis atrata—Schwartzer Schwann..	35 days	162
<b>Cathartidae</b>		
Sarcorhamphus gryphus—Kondor.....	55 days	9
Condor (in captivity) .....	54 days	25
Sarcorhamphus gryphus Condor.....	54 days	2
Cathartes Californicus—California Vulture .....	29 to 31 days	1
<b>Gypogeronidae</b>		
Serpentarius reptilivorus—Secretary Vulture .....	about 6 weeks	1
<b>Falconidae</b>		
Prairie Falcon .....	21 to 28 days	44
Falco peregrinus—Peregrine Falcon.	18 to 19 days	1
Falco peregrinus anatum—Duck Hawk..	28 days	3
Duck Hawk .....	28? days	44
Falco subbuteo—Hobby.....	21 days	1
Falco columbarius columbarius—Pigeon Hawk .....	21? days	3
Pigeon Hawk .....	21? days	44
Tinnunculus alaudarius—Kestrel.....	27-28 days	1
Falco sparverius sparverius—Sparrow Hawk .....	29 to 30 days	3
Sparrow Hawk .....	21? days	44
Sparrow Hawk .....	29-30 days	56
Sparrow Hawk .....	about 21 days	35
Sparrow Hawk .....	29-30 days	64
Audubon's Caracara .....	28? days	44

Family—Species	Period	Authority
<b>Buteonidae</b>		
<i>Pernis apivorus</i> —Honey Buzzard.....	21 days	1
<i>Circus hudsonius</i> —Marsh Hawk.....	26 to 28 days	3
<i>Marsh Hawk</i> .....	“is nearly 4 weeks”	57
<i>Marsh Hawk</i> .....	31 days	43
<i>Marsh Hawk</i> .....	21 days	44
<i>Circus aeruginosus</i> —Marsh Harrier.....		
.....	“21 to 24 days group”	1
<i>Circus cyaneus</i> .....	“21 to 24 days group”	1
<i>Accipiter velox</i> —Sharp-shinned Hawk.....	21 days	3
<i>Sharp-shinned Hawk</i> .....	21 days	44
<i>Accipiter cooperi</i> —Cooper’s Hawk.....	24 days	3
<i>Cooper’s Hawk</i> .....	24 days	44
<i>Accipiter nisus</i> —Sparrow Hawk.....	21 days	1
<i>American Goshawk</i> .....	28? days	44
<i>Harris Hawk</i> .....	28? days	44
<i>Buteo borealis borealis</i> —Red-tailed Hawk.....	28 days	3
<i>Red-tailed Hawk</i> .....	28 days	44
<i>Red-tailed Hawk</i> .....	32 days	194
<i>Buteo borealis calurus</i> —Western Red-tailed Hawk.....	28 days	3
<i>Western Red-tailed Hawk</i> .....	28? days	44
<i>Buteo lineatus</i> —Red-shouldered Hawk.....		
.....	27 to 28 days	3
<i>Red-shouldered Hawk</i> .....	28? days	44
<i>Red-shouldered Hawk</i> .....	“less than 28 days”	57
<i>Zone-tailed Hawk</i> .....	28? days	44
<i>Buteo swainsoni</i> —Swainson’s Hawk.....	25-28 days	3
<i>Swainson’s Hawk</i> .....	28? days	44
<i>Swainson’s Hawk</i> .....	about 25 days	58
<i>Buteo platypterus</i> —Broad-winged Hawk.....		
.....	23-25 days	3
<i>Broad-winged Hawk</i> .....	21-24 days	44
<i>Buteo vulgaris</i> —Buzzard.....	21 days	1
<i>Buteo vulgaris</i> —Common Buzzard.....	31 days	2
<i>Urubitinga anthracina</i> —Mexican Goshawk (Black Hawk).....	24-28 days	3
<i>Mexican Goshawk</i> .....	21-28 days	44
<i>Archibuteo lagopus sancti-johannis</i> —Rough-legged Hawk .....	28 days	3
<i>American Rough-legged Hawk</i> .....	28? days	44
<i>Archibuteo ferrugineus</i> — Ferruginous Rough-legged Hawk .....	28 days	3
<i>Ferruginous Rough-legged Hawk</i> .....	28? days	44
<i>Ferruginous Rough-legged Hawk</i> .....	about 25 days	59
<i>Milvus ictinus</i> —Kite.....	“21 to 24 days group”	1
<i>Pandion haliaetus carolinensis</i> —Osprey.....	27-28 days	3
<i>Osprey</i> .....	21-28 days	44

Family—Species	Period	Authority
Fish Hawk .....	28 days	65
Osprey .....	24-28? days	66
<i>Aquila chrysaëtus</i> —Golden Eagle.....	30 days	1
<i>Aquila chrysaëtos</i> —Golden Eagle.....	35 days	3
Golden Eagle .....	28 days	44
Golden Eagle 25-35 days (prob. avg.) .....	30 days	60
Golden Eagle .....	"at least 32 days"	61
Golden Eagle .....	35 days	63
Golden Eagle .....	30 days	63
<i>Aquila naevia</i> —Spotted Eagle.....	21 days	1
<i>Aquila imperialis</i> —Imperial Eagle.....	35 days	1
<i>Haliaeetus albicilla</i> —Grey Sea Eagle.....	30 days	3
<i>Haliaeetus albicillis</i> —Gray Sea Eagle.....	"lasts about a month"	60
<i>Haliaeetus leucocephalus</i> —Bald Eagle.....	30 days	3
Bald Eagle .....	28 days	44
Bald Eagle .....	36 days	57
Bald Eagle .....	30-36 days	60
Bald Eagle (in captivity) .....	31 days	99
<i>Nesaetus fasciatus</i> —Bornelli's Eagle.....	40 days	1
<i>Vultur monachus</i> —Mönchsgreier.....	51 days	9
<i>Vulture monachus</i> —Kuttengeier .....	51 days	162
<i>Gyps fulvus</i> —Griffon Vulture.....	42 days	176
<i>Gypaetus barbatus</i> —Avvoltorio degli ag- nelli (Lämmergeier) .....	20 days	12
<i>Cercaëtus gallicus</i> —Short-toed Eagle.....	about 28 days	1
<b>Megapodiidae</b>		
<i>Lipoa ocellata</i> —Malles Fowl ....."from 38 to 41 days"	191	
<i>Lipoa ocellata</i> —Mound Bird.....		
....."takes a little over 5 weeks"	131	
<i>Lipoa ocellata rosinae</i> —Malles Fowl ..58 to 77 days	142	
<i>Megapodius duperreyi</i> —Scrub Fowl.....		
.....from 5 to 6 weeks	14	
<i>Megapodius duperreyi</i> —Scrub Fowl ..about 6 weeks	131	
<i>Catheturus lathami</i> —Bush Turkey ..about 6 weeks	14	
<i>Catheturus lathami</i> —Bush Turkey ..about 6 weeks	131	
<b>Cracidae</b>		
<i>Crax globicera</i> —Globose Currassow		
(Probably 28) .....	28-31 days	169
<i>Crax carunculata</i> —Yarrell's Hokko .....	28-29 days	162
<b>Phasianidae</b>		
<i>Colinus virginianus</i> —Virginian Colin.....		
....."toward 4 weeks"	1	
<i>Colinus virginianus</i> —Bobwhite .....	24 days	3
Bobwhite Quail .....	24 days	44
Bobwhite .....	24 days	45

Family—Species	Period	Authority
Bobwhite .....	24 days	35
Bobwhite (Quail) .....	23 to 24 days	95
Plumed Quail .....	21 days	44
Scaled Quail .....	21 days	44
Callipepla californica—California Part-ridge .....	21 days	1
Lophortyx californica californica—California Quail .....	24? days	3
California Quail .....	21-28 days	44
Lophortyx californica vallicola—Valley Quail .....	24? days	3
Valley Quail .....	28 days	44
Lophortyx californica gambeli—Gambel's Quail .....	24 days	3
Gambel's Quail .....	21-24 days	44
Caccabis rufa—Partridge (Red-Legged) .....	23 & 24 days	1
Caccabis petrosa—Barbary Partridge .....	19 or 20 days	1
Partridge (Sp?) .....	24 days	33
Perdix perdix—Hungarian Partridge .....	21 (to 26?) days	46
Perdix perdix—Rephahn .....	24 days	162
Perdix Cinerea—Partridge .....	25 days	1
Coturnix communis—Quail .....	21 days	1
Synoecus australis—Brown Quail, under hen .....	14-21 days	14
Coturnix novae-zealandiae—New Zealand Quail .....	21 days	42
Coturnix novae-zealandiae—New Zealand Quail .....	21 days	1
Tetrao tetrix—Black Grouse .....	26 days	1
Tetrao urogallus—Capercaillie .....	26 days	1
Dusky Grouse .....	18-24 days	44
Dendragapus obscurus obscurus—Dusky Grouse .....	24 days	3
Sooty Grouse .....	18-24 days	44
Dendragapus obscurus fuliginosus—Sooty Grouse .....	24 days	3
Canachites canadensis canace—Spruce Grouse .....	17 days	180
Bonasa umbellus—Ruffed Grouse .....	21 days	1
Bonasa umbellus umbellus—Ruffed Grouse .....	21 days	3
Canada Ruffed Grouse .....	17 days	35
Ruffed Grouse .....	24-28 days	44
Ruffed Grouse .....	24 days	95
Bonasa umbellus togata—Canadian Ruffed Grouse .....	21 days	3
Canada Grouse .....	17? days	44

Family—Species	Period	Authority
Canada Grouse . . . . .	24-28? days	44
Bonasa betulina—Hazel Grouse . . . . .	21 days	1
Lagopus lagopus lagopus—Willow Ptarmigan . . . . .	18? days	3
Lagopus lagopus—Schnee Huhn . . . . .	26 days	9
Lagopus lagopus—Schnee Huhn . . . . .	26 days	162
Willow Ptarmigan . . . . .	17 days	44
Lagopus rupestris—Rock Ptarmigan . . . . .	24 days	1
Lagopus scoticus—Red Grouse . . . . .	24 days	1
Lagopus albus—Willow Ptarmigan . . . . .	24 days	1
Tympanuchus americanus americanus—Prairie Chicken . . . . .	21 days	3
Prairie Hen . . . . .	21-28 days	44
Heath Hen . . . . .	24 days	47
Cupidonia cupido—Prairie Hen . . . . .	18 or 19 days	1
Columbian Sharp-tail Grouse . . . . .	21 days	44
Pediaecetes phasianellus columbianus—Columbian Sharp-tail Grouse . . . . .	21 days	3
Prairie Sharp-tail Grouse . . . . .	21 days	44
Pediaecetes phasianellus campestris—Prairie Sharp-tail Grouse . . . . .	21 days	3
Centrocercus urophasianus—Sage Grouse . . . . .	22 days	3
Tetrao urophasianus—Sage Grouse . . . . .	21-22 days	1
Sage Hen . . . . .	21 days	44
Sage Hen . . . . .	“about 3 weeks”	48
Meleagris gallopavo silvestris—Wild Turkey . . . . .	28 days	3
Meleagris gallopavo—Turkey . . . . .	26-28 days	1
Wild Turkey . . . . .	28 days	44
Mexican Wild Turkey . . . . .	28 days	44
Meleagris gallo-pavo—Domestic Turkey . . . . .	28 days	1
Meleagris americana—Domestic Turkey . . . . .	“four weeks of incubation”	49
Turkey . . . . .	28 days	8
Turkey . . . . .	28 days	33
Numida meleagris—Guinea Fowl . . . . .	25 days	1
Numida meleagris—Guinea Fowl . . . . .	28? days	51
Guinea . . . . .	25 days	33
Guinea Hen . . . . .	28 days	8
Ceriornis satyra — Horned Tragopan (Horned Pheasant) . . . . .	28 days	1
Ceriornis temmincki—Temminck's Tragopan . . . . .	28 days	1
Lophophornis impeyanus — Himalayan Monal . . . . .	28 days	1
Crossoptilon mantchuricum—Mantchurian Crossoptilon . . . . .	28 or 30 days	1

Family—Species		Period	Authority
<i>Euplocamus albi-cristatus</i> —White-crested			
Kaleege .....	26 days		1
<i>Euplocamus nycthemerus</i> —Silver Pheasant .....	26 days		1
<i>Euplocamus nycthemerus</i> —Silver Pheasant (under hen) .....	26 days	108	
<i>Euplocamus melanotus</i> — Black-backed			
Kaleege .....	24 days		1
<i>Euplocamus Horsfieldi</i> —Purple Kaleege .....	24 days		1
<i>Gennaeus</i> , species of .....	24-25 days	97	
<i>Gennaeus nycthemerus</i> .....	26 days	162	
<i>Gennaeus lineatus</i> .....	26 days	162	
<i>Gennaeus melanotus</i> .....	26 days	162	
<i>Gennaeus albocristatus</i> .....	26 days	162	
<i>Phasianus colchicus</i> —Common Pheasant .....	23 days		1
<i>Phasianus colchicus</i> —English Pheasant .....	23-24 days		3
<i>Phasianus mongolicus</i> .....	24-25 days	162	
<i>Phasianus versicolor</i> .....	26 days	162	
<i>Phasianus torquatus</i> .....	26 days	162	
<i>Phasianus principalis</i> —Prince of Wales Pheasant .....	24 days	108	
<i>Phasianus reevesi</i> —Reeves's Pheasant .....	24 days	108	
<i>Syrmaticus reevesii</i> .....	24-25 days	162	
<i>Syrmaticus reevesii</i> —Reeves's .....	24 days	108	
Pheasant (sp.?) .....	25 days	33	
Pheasant (sp.?) .....	24 days	8	
Pheasant (sp.?) .....	23-24 days	25	
Pheasant (sp.?) .....	24 days	50	
Pheasant Ring-neck .....	24 days	108	
<i>Syrmaticus wallichii</i> —Cheer Pheasant .....	28 days		1
<i>Calophasis mikado</i> —Mikado .....	28 days	68	
<i>Calophasis ellioti</i> .....	24-25 days	162	
<i>Thaumalea picta</i> —Golden Pheasant .....	22 days		1
Golden Pheasant .....	21 days	108	
<i>Chrysolophus pictus</i> —Golden Pheasant .....	21-22 days	97	
<i>Chrysolophus pictus</i> —Gold Fasan .....	23-24 days	162	
<i>Chrysolophus amherstiae</i> —Lady Amherst Pheasant .....	22-23 days	97	
<i>Chrysolophus amherstiae</i> —Amherst Fasan .....	23-24 days	162	
Gallus various—Forked-tail Jungle Fowl .....	21 days	1	
Gallus domesticus—Hen (Dorking var.) .....	20-21 days		1
Hen .....	21 days	33	
Hen .....	21 days	8	
Gallus domesticus—Bantam .....	21 days	1	
<i>Polyplectron chinquis</i> —Peacock Pheasant .....	21 days	9	
<i>Polyplectron chinquis</i> —Peacock Pheasant .....	21 days	1	
<i>Argus giganteus</i> —Argus Pheasant .....	24 days	1	

Family—Species	Period	Authority
<i>Argusianus argus</i> —Argus.....	26 days	9
<i>Pavo cristatus</i> —Peafowl.....	28 days	1
Peafowl .....	28 days	33
Peafowl .....	28 days	8
<b>Rallidae</b>		
<i>Rallus Crepitans</i> —Clapper Rail.....	14 days	1
<i>Porzana carolina</i> —Sora Rail.....	14? days	3
<i>Porzana maruetta</i> —Spotted Crake.....	21 days	1
<i>Porzana parvia</i> —Little Crake.....	21-24 days	1
<i>Crex pratensis</i> —Corn Crake.....	21-24 days	1
<i>Gallinula chloropus</i> —Moor Hen.....	21 days	1
<i>Porphyrio caeruleus</i> —Purple Gallinule.....	23-25 days	130
<i>Ocydromus australis</i> —Weka Ralle.....	28 days	9
<i>Eulabeornis Ypacha</i> —Ypaka Ralle.....	21 days	9
<i>Fulica atra</i> —Coot (European).....	22 days	1
<i>Fulica americana</i> —Coot.....	14 days	3
<b>Gruidae</b>		
<i>Grus communis</i> —Crane.....	28 days	1
<i>Grus japonensis</i> —Mandschurische Kran- ich .....	30-31 days	9
<i>Grus viridirostris</i> —Mantehurian Crane.....	30 days	1
<i>Grus canadensis</i> —Kanadische Kranich.....	33 days	162
<i>Anthropoides paradisea</i> —Paradieskranich .....	34-35 days	9
<i>Anthropoides virgo</i> —Jungfernkranich.....	28 days	9
<b>Cariamidae</b>		
<i>Cariama Cristata</i> —Seriema .....	28 days	9
<b>Otididae</b>		
<i>Otis Tarda</i> —Great Bustard.....	“about 4 weeks”	1
<b>Rhinochetidae</b>		
<i>Rhinochetus jubatus</i> —Kagu (in incuba- tor) .....	36 days	10
<i>Rhinochetus jubatus</i> —Cagon (in captiv- ity) .....	36 days	143
<b>Eurypygidae</b>		
<i>Eurypyga helias</i> —Sun Bittern.....	27 days	1
<b>Charadriidae</b>		
<i>Recurvirostra avocetta</i> —Avocet.....	17-28 days	1
<i>Scolopax rusticula</i> —Woodcock.....	20 days	1
<i>Philohela minor</i> —Woodcock.....	20-21 days	3
<i>Gallinago major</i> —Great Snipe.....	16 to 18 days	1
<i>Gallinago caelestis</i> —Common Snipe.....	20 days	1
<i>Tringa alpina</i> —Dunlin.....	22 days	1
<i>Totanus hypoleucus</i> —Common Sandpiper .....	22 days	1
<i>Totanus calidris</i> —Redshank.....	14 to 16 days	1
<i>Totanus calidris</i> —Redshank.....	23 days	2
<i>Totanus calidris</i> —Pettigola.....	23 days	12

Family—Species	Period	Authority
<i>Totanus ochropus</i> —Green Sandpiper	21 to 24 days	1
<i>Machetes pugnax</i> —Ruff	16 days	1
<i>Bartramia longicauda</i> —Bartram's Sandpiper	17? days	3
<i>Actitis macularius</i> —Spotted Sandpiper	15-16 days	3
<i>Numenius arquata</i> —Curlew	30 days	1
<i>Haematopus vulgaris</i> —Lapwing	25 to 26 days	1
<i>Eudromias morinellus</i> —Dotterel	18 or 20 days	1
<i>Zonifer tricolor</i> —Brust-Schild Kubitz	28 days	162
<i>Charadrius pluvialis</i> —Golden Plover	27 days	1
<i>Aegialitis hiaticula</i> —Ringed Plover	22 and 23 days	1
<i>Aegialitis vociferus</i> —Killdeer (about)	26 days	149
<i>Oxyechus vociferus</i> —Killdeer (probably 26½-27½)	28 days	172
<i>Haematopus palliatus</i> —Oystercatcher	14? days	3
<i>Recurvirostra ostralegus</i> —Oystercatcher	23 to 24 days	1
<b>Oedicinemidae</b>		
<i>Oedicemus scolopax</i> —Stone Curlew	16 or 17 days	1
<b>Laridae</b>		
<i>Stercorarius catarrhactes</i> —Great Skua	about 4 weeks	1
<i>Megalestris maccormicki</i> —Skua Gull	4 weeks	20
<i>Rissa tridactyla</i> —Kittiwake	26 days	1
<i>Larus glaucus</i> —Glaucus Gull	28 days	1
<i>Larus Marinus</i> —Mantel Möwe	26 days	9
<i>Larus argentatus</i> —Herring Gull	26 days	1
<i>Larus argentatus</i> —Herring Gull	26 or 27 days	3
Herring Gull	one set 24 days	22
Herring Gull	two sets 25 days	22
Herring Gull	five sets 26 days	22
Herring Gull	four sets 27 days	22
Herring Gull	three sets 28 days	22
<i>Larus ridibundus</i> —Black-headed Gull	22 and 23 days	1
<i>Larus franklini</i> —Franklin's Gull	18 or 20 days	3
Franklin's Gull	18 or 20 days	23
<i>Sterna caspia</i> —Caspian Tern	about 20 days	1
<i>Sterna Fluvialis</i> —Common Tern	almost exactly 21 days	1
<i>Sterna Fluvialis</i> —Common Tern	22 & 23 days	1
<i>Sterna hirundo</i> —Common Tern	21 days	3
<i>Sterna hirundo</i> —Rondine di Mare	21-23 days	12
<i>Sterna arctica</i> —Arctic Tern	15 or 16 days	1
<i>Sterna dougalli</i> —Roseate Tern	21 days	3
<i>Sterna minuta</i> —Little Tern	14 to 16 days	1

Family—Species	Period	Authority
<i>Sterna fuscata</i> —Sooty Tern.....	26-29 days	3
<i>Sooty Tern</i> .....	26 days	24
<i>Sterna fuliginosa</i> —Sooty Tern.....	15 or 16 days	14
<i>Hydrochelidon niger surinamensis</i> —Black Tern .....	17 to 19? days	187
<i>Hydrochelidon niger</i> —Black Tern.....	15 or 16 days	1
<i>Noddy Tern</i> .....	32-35 days	24
<i>Anous stolidus</i> —Noddy .....	35-36 days	3
<i>Anous stolidus</i> —Noddy Tern.....	35-36 days	106
<b>Alcidae</b>		
<i>Fratercula arctica</i> —Puffin.....	36 days	1
<i>Fratercula corniculata</i> —Horned Puffin (Est. by W.H.B.) .....	25-32 days	21
<i>Cephus grylle</i> —Black Guillemot.....	21 days	3
<i>Uria grylle</i> —Black Guillemot.....	24 days	1
<i>Lomvia troile</i> —Guillemot.....	30 & 33 days	1
<i>Alca torda</i> —Razor-bill .....	30 days	1
<b>Pteroclidae</b>		
<i>Pteroclurus alchata</i> —Pin-tailed Sand Grouse .....	“about 25 days”	1
<i>Syrrhaptes paradoxus</i> —Pallas’s Sand Grouse .....	28 days	1
<b>Columbidae</b>		
<i>Columba fasciata fasciata</i> —Band-tailed Pigeon .....	18-20 days	3
<i>Band-tailed Pigeon</i> .....	18-20 days	44
<i>Red-billed Pigeon</i> .....	18-20 days	44
<i>Columba livia</i> —Rock Dove.....	16 to 18 days	1
<i>Columba livia</i> —Domestic Dove.....	14 days	3
<i>Columba livida</i> —Tauben .....	17-18 days	9
Pigeon .....	18 days	8
Pigeon.....(almost exactly) 17 days		92
<i>Columba domestica</i> —Rock Dove....	“about 2 weeks”	52
<i>Columba aenae</i> —Stock Dove.....	17 to 18 days	1
<i>Columba palumbus</i> —Ring Dove.....	17 days	1
<i>Ectopistes migratorius</i> —Passenger Pigeon .....	16 days	1
<i>Ectopistes migratorius</i> —Passenger Pigeon .....	14 days	3
Passenger Pigeon .....	18-20 days	44
Passenger Pigeon....(“almost to a day”) 14 days		53
<i>Zenaidura macroura carolinensis</i> —Mourning Dove .....	12-14 days	3
Mourning Dove .....	13 days	92
Mourning Dove .....	14 days	44
Mourning Dove .....	14 days	97
<i>Melopelia asiatica</i> —White-winged Dove..	18 days	3

Family—Species	Period	Authority
White-winged Dove .....	18 days	44
Turtur risorius—Collared Turtle Dove...	15 days	1
Turtur risorius—Ring Dove.....	about 15 days	92
Turtur communis—Turtle Dove.....	16 to 17 days	1
Chaemepelia passerina terrestris—Ground Dove .....	12 days	3
Ground Dove .....	14 days	44
Mexican Ground Dove.....	14 days	44
Ocyphaps lophotes—Crested Pigeon.....	14 days	1
Ocyphaps lophotes—Crested Doye .....	about 14 days	97
Caloenas nicobarica—Nicobar Pigeon.....	28 days	1
Goura coronata—Crowned Pigeon.....	28 days	1
Crowned Pigeons (Gouridae) .....	28 days	116
<b>Cuculidae</b>		
Geococcyx californicus—Roadrunner.....	18 days	3
Coccyzus americanus americanus—Yellow billed Cuckoo.....	14 days	3
Coccyzus americanus americanus—Yellow- billed Cuckoo.....	about 14 days	35
Coccyzus erythrophthalmus — Black-billed Cuckoo .....	14 days	3
Cuculus canorus—Kuckuck.....	11 days	9
Cuculus canorus—Cuckoo.....	13 to 14 days	1
Cuculus pallidus—Pallid Cuckoo .....	about 12 or 14 days	14
Chaleococcyx lucidus—Broad-billed Bronze Cockoo .....	19? days	14
<b>Trichoglossidae</b>		
Trichoglossus novae-hollandiae—Swain- son's Lorikeet.....	21 days	1
<b>Psittacidae</b>		
Cacatua cristata—Great White-crested Cockatoo .....	21 days	1
Cacatua goffini—Goffin's Cockatoo.....	21 days	1
Cacatua rosicapilla—Roseate Cockatoo .....	“about 21 days”	1
Colopsitta novae-hollandiae— Cockateel .....	“about 20 days”	1
Licmetis nasica—Long-billed Cockatoo .....	“about a month”	14
Licmetis tenuirostris—Slender-billed Cockatoo .....	“about 21 days”	1
Cyanorhamphus novae-zealandiae—New Zealand Parrakeet .....	“about 18 days”	1
Ara ararauna—Blue and Yellow Macaw .....	20-25 days	1

Family—Species	Period	Authority
<i>Melopsittacus undulatus</i> —Warbling Grass Parrakeet	"about 20 days"	14
<i>Melopsittacus undulatus</i> —Waved Parrakeet	16 to 20 days	1
<i>Neophema (?) venusta</i> —Blue-winged Grass Parrakeet	19-22 days	14
<i>Euphema bourkei</i> —Bourke's Parrakeet	"about 17 days"	1
<i>Euphema Pulchella</i> —Torquoisine Parrakeet	"about 18 days"	1
<i>Euphema splendida</i> —Splendid Grass Parrakeet	"about 18 days"	1
Parrots—period of incubation is	approximately 21 days	10
<i>Psephotus haematonotus</i> —Blood-rumped Parrakeet	about 17 days	1
<i>Lathamus discolor</i> —Swift Parrakeet	21 days	1
Carolina Parrakeet (in captivity)	21 days	98
Parrots—Small	16-20 days	162
Parrots—Large	25-30 days	162
Coraciidae		
<i>Coracias garrulus</i> —Roller	18 to 20 days	1
Alcedinidae		
<i>Ceryle alcyon</i> —Belted Kingfisher	16 days	1
<i>Ceryle alcyon</i> —Belted Kingfisher	23-24 days	3
<i>Alcedo insipida</i> —Kingfisher	14 days	1
<i>Halcyon vagans</i> —New Zealand Kingfisher	17? days	42
<i>Halcyon vagans</i> —New Zealand Kingfisher	19 days	1
<i>Halycon sanctus</i> —Sacred Kingfisher	about 17 days	14
Upupidae		
<i>Upupa epops</i> —Hoopoe	16 days	1
Strigidae		
<i>Aluco pratincola</i> —Barn Owl	21-24 days	3
Barn Owl	21? days	44
Barn Owl	3 to 3½ weeks	57
<i>Asio otus</i> —Long-eared Owl	27 days	1
<i>Asio wilsonianus</i> —Long-eared Owl	21 days	3
American Long-eared Owl	21? days	44
Long-eared Owl	"about 3 weeks"	30
Long-eared Owl	"about 21 days"	35
Long-eared Owl	"about 3 weeks"	57
<i>Asio flammeus</i> —Short-eared Owl	21 days	3
Short-eared Owl	21? days	44

Family—Species	Period	Authority
<i>Scleoglaux albifacies</i> —Laughing Owl	25 days	42
Barred Owl	21-28 days	44
<i>Syrnium aluco</i> —Tawney Owl	21 days	1
<i>Cryptoglaux arcadia</i> —Saw-whet Owl	21? days	3
Saw-whet Owl	21? days	44
<i>Otus asio asio</i> —Screech Owl	21-26 days	3
Screech Owl	21 days	44
Screech Owl	25 days	67
Screech Owl	22 days	57
Macfarland's Screech Owl	21-28? days	44
<i>Bubo virginianus virginianus</i> —Great-horned Owl	28-30 days	3
Great-horned Owl	"probably about 4 weeks"	57
Great-horned Owl	21-28 days	44
<i>Bubo virginianus pallescens</i> —Western Horned Owl	28 days	3
Western Great-horned Owl	28? days	44
<i>Bubo virginianus pacificus</i> —Pacific Horned Owl	28 days	3
<i>Bubo turcomanus</i> —Turkman Uhu	27-33 days	9
<i>Bubo Ignavus</i> —Eagle Owl	21 to 24 days	1
<i>Nyctea scandiaca</i> —Snowy Owl	32 days	1
<i>Speotyto cunicularia hypogaea</i> —Burrowing Owl	21-28 days	3
Burrowing Owl	21? days	44
<i>Athene noctua</i> —Little Owl	14 to 16 days	1
<i>Micropallas whitneyi</i> —Elf Owl	14 days	3
Elf Owl	14? days	44
<b>Caprimulgidae</b>		
<i>Antrostomus vociferus</i> —Whip-poor-will	17 days	3
<i>Chordeiles virginianus</i> —Nighthawk	16 to 18 days	3
<i>Chordeiles virginianus</i> —Nighthawk	"a fortnight"	1
<i>Caprimulgus europaeus</i> —Nightjar	15 days	1
<b>Trochilidae</b>		
<i>Trochilus colubris</i> —Ruby-throated Hummingbird	10 days	1
<i>Trochilus colubris</i> —Ruby-throated Hummingbird	14 days	188
<i>Trochilus colubris</i> —Ruby-throated Hummingbird	14 days	65
<i>Trochilus colubris</i> —Ruby-throated Hummingbird	15 days	179
<i>Archilochus colubris</i> —Ruby-throated Hummingbird	14 days	3
<i>Archilochus alexandri</i> —Black-chinned Hummingbird	13 days	3

Family—Species	Period	Authority
<i>Calypte costae</i> —Costa's Hummingbird . . . . .	14 days	3
<i>Calypte anna</i> —Anna's Hummingbird . . . . .	14 days	3
<i>Selasphorus rufus</i> —Rufous Hummingbird . . . . .	12 days	3
<i>Florisuga atra</i> —Black Hummingbird . . . . .	12 days	1
<i>Hummingbirds</i> . . . . .	12-14-18 days	71
<b>Micropodidae</b>		
<i>Cypselus apus</i> —Swift . . . . .	16 or 17 days	1
<i>Cypselus melba</i> —Alpine Swift . . . . .	"a little over 2 weeks"	1
<i>Chætura pelagica</i> —Chimney Swift . . . . .	18 days	3
<i>Chætura pelagica</i> —Chimney Swift . . . . .	19 days	184
<i>Chimney Swift</i> . . . . .	22 days	194
<b>Trogonidae</b>		
<i>Hapaloderma narina</i> —Narina Tropicbird . . . . .	20 days	1
<b>Picidae</b>		
<i>Gecinus viridis</i> —Green Woodpecker . . . . .	16 to 18 days	1
<i>Dendrocopos major</i> —Great Spotted Woodpecker . . . . .	14 to 16 days	1
<i>Dendrocopos medius</i> —Middle Spotted Woodpecker . . . . .	15 days	1
<i>Dendrocopos minor</i> —Lesser Spotted Woodpecker . . . . .	14 days	1
<i>Dryobates villosus villosus</i> —Hairy Woodpecker . . . . .	14 days	3
<i>Dryobates villosus hylocosopus</i> —Cabanis' Woodpecker . . . . .	15 days	3
<i>Dryobates pubescens medianus</i> —Downy Woodpecker . . . . .	12 days	3
<i>Dryobates scalaris bairdi</i> —Texas Woodpecker . . . . .	13 days	3
<i>Xenopicus albolarvatus</i> —White-headed Woodpecker . . . . .	14 days	3
<i>Picoides americanus americanus</i> —Three-toed Woodpecker . . . . .	14 days	3
<i>Sphyrapicus varius nuchalis</i> —Red-naped Sapsucker . . . . .	14 days	3
<i>Sphyrapicus ruber ruber</i> —Red-breasted Sapsucker . . . . .	12-14 days	3
<i>Phlaeotomus pileatus pileatus</i> —Pileated Woodpecker . . . . .	18 days	3
<i>Picus martius</i> —Great Black Woodpecker . . . . .	16 to 18 days	1
<i>Melanerpes erythrocephalus</i> —Red-headed Woodpecker . . . . .	14 days	3
<i>Asyndesmus lewisi</i> —Lewis's Woodpecker . . . . .	14 days	3
<i>Centurus carolinus</i> —Red-bellied Woodpecker . . . . .	14 days	3

Family—Species		Period	Authority
Centurus aurifrons—Golden-fronted Wood-pecker	.....	14 days	3
Centurus uropygilais—Gila Woodpecker	.....	14 days	3
Colaptes auratus luteus—Flicker	.....	11-14 days	3
Flicker	.....	11-12 days	70
Flicker	.....	“about 16 days”	69
Iynx torquilla—Wryneck	.....	14 days	1
Tyrannidae			
Muscivora forficata—Scissor-tailed Fly-catcher	.....	12-13 days	3
Tyrannus tyrannus—Kingbird	.....	12-13 days	3
Kingbird	.....	14 days	43
Tyrannus verticalis—Arkansas King-bird	.....	12-13 days	3
Tyrannus verticalis—Arkansas Kingbird	.....	14 days	78
Tyrannus vociferans—Cassin’s King-bird	.....	12-14 days	3
Myiarchus crinitus—Crested Fly-catcher	.....	13-15 days	3
Myiarchus cinerascens cinerascens—Ash-throated Flycatcher	.....	15 days	3
Sayornis phoebe—Phoebe	.....	12-14 days	3
Phoebe	.....	15 days	72
Phoebe	.....	15-16 days	189
Sayornis sayus—Say’s Phoebe	.....	12 days	3
Say’s Phoebe	.....	12? days	43
Nuttalornis borealis—Olive-sided Fly-catcher	.....	14 days	3
Myiochanes virens—Wood Pewee	.....	12-13 days	3
Empidonax difficilis difficilis—Western Flycatcher	.....	12 days	3
Empidonax trailli trailli—Traill’s Fly-catcher	.....	12 days	3
Empidonax trailli alnorum—Alder Fly-catcher	.....	12 days	3
Empidonax minimus—Least Flycatcher	.....	12 days	3
Least Flycatcher	.....	14 days	43
Empidonax wrighti—Wright’s Fly-catcher	.....	12 days	3
Pyrocephalus rubinus mexicanus—Vermillion Flycatcher	.....	12 days	3
Menuridae			
Menura superba—Lyre Bird (“sometimes extends over a month”)	.....	31 days	14
Lyre Bird	.....	“about a month”	25
Menura victorae—Victoria Lyre Bird	.....	“about 5 or 6 weeks”	17
Menura victoriae—Victoria Lyre Bird	.....	51? days	14

Family—Species		Period	Authority
<b>Alaudidae</b>			
<i>Otocoris alpestris leucolaema</i> —Horned Lark	.....	11-14 days	146
<i>Alauda arvensis</i> —Sky Lark	.....	14 days	1
<i>Alauda arvensis</i> —Lodola	.....	13-14 days	12
<i>Alauda arvensis</i> —Skylark	.....	13-14 days	2
<i>Alauda arborea</i> —Wood Lark	.....	about 15 days	1
<i>Alanda cristata</i> —Crested Lark	.....	“about a fortnight”	1
<b>Motacillidae</b>			
<i>Motacilla alba</i> —White Wagtail	.....	14 days	1
<i>Motacilla alba</i> —Ballerina	.....	14 days	12
<i>Motacilla lugubris</i> —Pied Wagtail	.....	13 days	1
<i>Motacilla lugubris</i> —Pied Wagtail	.....	“middle of the 14th day”	2
<i>Anthus pratensis</i> —Meadow Pipit	.....	13 and 14 days	1
<i>Anthus trivialis</i> —Tree Pipit	.....	13 days	1
<b>Pycnonotidae</b>			
<i>Pycnonotus leucotis</i> —Weissorbulbul	.....	11 days	162
<b>Muscicapidae</b>			
<i>Muscicapa grisola</i> —Spotted Flycatcher	.....	13 days	1
<i>Muscicapa atricapilla</i> —Pied Flycatcher	.....	14 days	1
<i>Rhipidura tricolor</i> —Black and White Fantail	.....	15 days	14
<i>Rhipidura albiscapa</i> —White-shafted Fantail	.....	16 days	14
<i>Rhipidura albiscapa</i> —White-shafted Fantail	.....	12 days	17
<i>Melurus superbus</i> —Superb Warbler	.....	about 14 days	17
<i>Melurus cyaneus</i> —Blue Wren	.....	14 days	14
<i>Gerygone albicularis</i> —White-throated Bush Warbler	.....	“about 12 days”	17
<i>Melanodryas petroeca</i> (?)—Hooded Robin	.....	16-17 days	14
<b>Turdidae</b>			
<i>Hylocichla mustelina</i> —Wood Thrush	.....	14 days	3
Wood Thrush	.....	12 days	35
<i>Hylocichla ustulata ustulata</i> —Russet-backed Thrush	.....	14 days	14
<i>Hylocichla ustulata swainsoni</i> —Olive-backed Thrush	.....	10-13 days	3
<i>Hylocichla guttata pallasi</i> —Hermit Thrush	.....	12 days	3
Hermit Thrush	.....	12 days	89
<i>Turdus musicus</i> —Song Thrush	.....	15 days	1
<i>Turdus viscivorus</i> —Missle Thrush	.....	15 days	1
<i>Turdus merula</i> —Blackbird	.....	14 and 15 days	1

Family—Species	Period	Authority
<i>Turdus merula</i> —Blackbird .....	15 days	2
<i>Merula merula</i> —Merlo .....	15 days	12
<i>Planesticus migratorius migratorius</i> —		
Robin .....	11-14 days	3
Robin (Eastern) .....	exactly 14 days	90
Robin .....	13-14 days	72
Robin .....	14 days	91
Robin (Western) .....	14 days	43
Robin (Western) .....	exactly 14 days	78
Accentor modularis—Hedge Sparrow .....	14 days	1
Ruticilla phoenicurus—Redstart .....	13 days	1
Ruticilla phoenicurus—Redstart .....	14th day	2
Ruticilla phoenicurus—Codirosso .....	14 days	12
Ruticilla titys—Black Redstart .....	13 days	1
Erithacus rubecula—Redbreast .....	14 days	1
Erithacus rubecula—Pettirosso .....	13-15 days	12
Erithacus rubecula—Redbreast .....	13-14 days	2
Daulias luscinia—Nightingale .....	“a fortnight”	1
Sialia sialis sialis—Bluebird .....	12 days	3
Sialia sialis sialis—Bluebird .....	14-15 days	96
<b>Mimidae</b>		
<i>Mimus polyglottos polyglottos</i> —Mocking- bird .....	10 days	3
<i>Mimus polyglottos</i> —Mocking-bird .....	14 days	1
<i>Dumetella carolinensis</i> —Catbird .....	12-13 days	195
Catbird .....	more than 11 days	43
<i>Toxostoma rufum</i> —Brown Thrasher .....	13-14 days	196
Brown Thrasher .....	12? days	80
<i>Toxostoma curvirostre curvirostre</i> —Curved- billed Thrasher .....	13 days	3
<b>Cinclidae</b>		
<i>Cinclus aquaticus</i> —Dipper .....	15 days	1
<b>Troglodytidae</b>		
<i>Thryothorus ludovicianus ludovicianus</i> —		
Carolina Wren .....	12 days	3
<i>Thryothorus ludovicianus miamensis</i> —		
Florida Wren .....	14 days	3
<i>Thryomanes bewicki</i> —Bewick’s Wren .....	10-15 days	3
<i>Troglodytes aëdon aëdon</i> —House Wren .....	11-13 days	3
<i>Troglodytes parvulus</i> —Wren .....	13 days	1
<i>Anorthura troglodytes</i> —Scricciolo .....	10 days	12
<i>Telmatodytes palustris palustris</i> —Long- billed Marsh Wren .....	10-13 days	3
<b>Chamaeidae</b>		
<i>Chamœa fasciata fasciata</i> —Wren Tit .....	15-18 days	128

Family—Species	Period	Authority
<b>Sylviidae</b>		
<i>Acrocephalus palustris</i> —Marsh Warbler...	13 days	1
<i>Acrocephalus turdoides</i> —Great Reed Warbler .....	14-15 days	1
<i>Acrocephalus phragmitis</i> —Sage Warbler..	15 days	2
<i>Sylvia curruca</i> —Lesser Whitethroat .....	12-14 days	1
<i>Sylvia cinerea</i> —Whitethroat .....	11-13 days	1
<i>Sylvia atricapilla</i> —Blackcap.....	14 days	1
<i>Sylvia hortensis</i> —Garden Warbler.....	15 days	1
<i>Sylvia sylvia</i> —Serpazzola .....	10 days	12
<i>Phylloscopus trochilus</i> —Willow Wren....	13 days	1
<i>Phylloscopus rufus</i> —Chiffchaff .....	13 days	1
<i>Sericornis frontalis</i> —White-browed Scrub Wren .....	21-23? days	14
<i>Prinia maculosa</i> —Capocier.....	14 days	1
<i>Geobasileus reguloides</i> —Buff-rumped Thornbill .....	“about 12 days”	17
<b>Regulidae</b>		
<i>Regulus cristatus</i> —Goldcrest.....	12 days	1
<b>Hirundinidae</b>		
<i>Progne subis subis</i> —Purple Martin....	12-15 days	3
<i>Martin</i> .....	12-15 days	81
<i>Pertocheildon lunifrons lunifrons</i> —Cliff Swallow .....	12-14 days	3
<i>Hirundo erythrogaster</i> —Barn Swallow...	11 days	3
<i>Hirundo erythrogaster</i> —Barn Swallow...	13 days	1
<i>Hirundo rustica</i> —Swallow.....	15 days	1
<i>Hirundo rustica</i> —Swallow .....	“second half of the 15th”	2
<i>Hirundo rustica</i> —Rondine.....	15 days	12
<i>Hirundo neoxena</i> —Welcome Swallow.....	14 days	17
<i>Iridoprocne bicolor</i> —Tree Swallow.....	14 days	3
<i>Chelidon urbica</i> —Martin.....	13 days	1
<i>Cotile riparia</i> —Sand Martin.....	12 or 13 days	1
<b>Ampelidae (or Bombycillidae)</b>		
<i>Bombycilla cedrorum</i> —Cedar Wax- wing .....	10-12 days	3
<i>Cedar Waxwing</i> .....	(probably) 14 days	82
<i>Bombycilla cedrorum</i> —Cedar Waxwing..	16 days	170
<b>Ptilogonatidae</b>		
<i>Phainopepla nitens</i> —Phainopepla .....	16 days	3
<b>Artamidae</b>		
<i>Artamus superciliosus</i> —Wood Swallow .....	about 14 days	116
<b>Laniidae</b>		
<i>Lanius ludovicianus ludovicianus</i> — Loggerhead Shrike .....	12-13 days	3

Family—Species		Period Authority
<i>Lanius ludovicianus migrans</i> —Migrant		
Shrike . . . . .	13-16 days	3
<i>Lanius excubitor</i> —Great Grey		
Shrike . . . . .	15 to 16 days	1
<i>Lanius minor</i> —Lesser Grey		
Shrike . . . . .	15 to 16 days	1
<i>Lanius collurio</i> —Red-backed Shrike . . . . .	14 days	1
<i>Lanius pomeranus</i> —Woodchat . . . . .	15 days	1
<i>Falcunculus frontatus</i> —Shrike Tit . . . . .	18-20 days	14
<b>Vireonidae</b>		
<i>Vireosylva olivacea</i> —Red-eyed Vireo . . . . .	12-14 days	3
<i>Vireo gilvus</i> —Warbling Vireo . . . . .	12 days	1
<i>Lanivireo solitarius solitarius</i> —Blue-headed		
Vireo . . . . .	10-11 days	3
<i>White-eyed Vireo</i> . . . . .	7?? days	35
<i>White-eyed Vireo</i> . . . . .	16 days	43
<b>Sittidae</b>		
<i>Sitta caesia</i> —Nuthatch . . . . .	13-14 days	1
<i>Sitta canadensis</i> —Red-breasted Nuthatch . . . . .	12 days	3
<b>Paridae</b>		
<i>Panthesetes atricapillus atricapillus</i> —		
Chickadee . . . . .	11-14 days	3
<i>Parus major</i> —Great Tit . . . . .	“end of 14th day”	2
<i>Parus caeruleus</i> —Blue Titmouse . . . . .	14 days	1
<i>Parus palustris</i> —Marsh Titmouse . . . . .	“about 13 days”	1
<i>Parus ater</i> —Coal Titmouse . . . . .	14 days	1
<i>Acredula rosea</i> —Long-tailed Titmouse . . . . .	11-13 days	1
<i>Panurus biarmicus</i> —Bearded Titmouse . . . . .	14 days	1
<b>Oriolidae</b>		
<i>Oriolus galbula</i> —Golden Oriole . . . . .	15 days	1
<b>Corvidae</b>		
<i>Pica rustica</i> —Magpie . . . . .	18 days	1
<i>Pica pica hudsonia</i> —Magpie . . . . .	16-18 days	3
Magpie . . . . .	“between 15 and 20 days”	43
<i>Cyanopolius cyanus</i> —Chinese Blue		
Magpie . . . . .	“about 18 days”	1
<i>Garrulus glandarius</i> —Jay . . . . .	16 days	1
<i>Cyanocitta cristata cristata</i> —Blue Jay . . . . .	15-17 days	3
<i>Cyanocitta cristata cristata</i> —Blue Jay . . . . .	17 days	190
<i>Cyanocitta stelleri stelleri</i> —Steller’s Jay . . . . .	16 days	3
<i>Cyanocitta stelleri frontalis</i> —Blue-fronted		
Jay . . . . .	16 days	3
<i>Aphelocoma woodhousei</i> —Woodhouse’s		
Jay . . . . .	16 days	3
<i>Aphelocoma californica</i> —California Jay . . . . .	16 days	3
<i>Aphelocoma sieberi arizonae</i> —Arizona		
Jay . . . . .	16 days	3

Family—Species	Period	Authority
Perisoreus canadensis canadensis—Canada		
Jay .....	16-18 days	3
Canada Jay .....	18? days	73
Corvus corax—Raven.....	18 to 19 days	1
Raven .....	18 to 19 days	25
Corvus corax principalis—Northern		
Raven .....	20-21 days	3
Corvus cryptoleucus—White-necked		
Raven .....	21 days	3
Corvus brachyrhynchos—Crow.....	18 days	3
Corvus ossifragus—Fish Crow.....	16-18 days	3
Corvus frugilegus—Rook.....	17 and 18 days	1
Corvus cornix—Hooded Crow.....	18 to 20 days	1
Corvus corone—Carrion Crow.....	18 to 20 days	1
Nicifraga caryocatactes—Nuthatches.....	17-18 days	1
Nicifraga columbiana—Clark's Nut- cracker .....	16-17 days	3
Nicifraga columbiana—Clarke's Nut- cracker .....	22 days	129
Cyanoccephalus cyanocephalus—Pinon Jay .....	16 days	3
Sturnidae		
Sturnus vulgaris—Starling.....	14 days	1
Sturnus vulgaris—Starling.....	11-14 days	3
Temenuchus pogadaram.....	14-16 days	116
Poliopsar malabaricus.....	14-16 days	116
Poliopsar andarrensis.....	14-16 days	116
Meliphagidae		
Ptilotis notata—Yellow-spotted Honey Eater .....	14 days	14
Ptilotis notata—Yellow-spot Honey Eater.	14 days	17
Zosteropidae		
Zosterops coerulescens—White Eye ..about 10 days		14
Zosterops coerulescens—Silver Eye.....	9 to 10 days	1
Zosterops palpebrosa—White Eyes.....	10-11 days	116
Certhiidae		
Certhia familiaris—Brown Creeper.....	12-13? days	88
Certhia familiaris—Tree Creeper.....	15 days	1
Mniotiltidae		
Protonotaria citrea—Prothonotary Warbler .....	14 days	3
Helmintheros vermiculus—Worm-eating Warbler .....	13 days	3
Vermivora pinus—Blue winged Warbler.....	10 days	3
Blue-winged Warbler .....	10 days	83
Blue-winger Warbler .....	10-14 days	84
Vermivora chrysoptera—Golden-winged Warbler .....	10 days	3

Family—Species	Period	Authority
<i>Vermivora rubicapillus rubicapillus</i>		
Nashville Warbler .....	11-12 days	3
<i>Dendroica aestiva aestiva</i> —Yellow		
Warbler .....	10-11 days	3
Yellow Warbler .....	10 days	43
Yellow Warbler .....	11 days	85
<i>Dendroica coronata</i> —Myrtle Warbler ..	12-13 days	3
<i>Dendroica magnolia</i> —Magnolia Warbler ..	12 days	3
<i>Magnolia</i> Warbler .....	12-13? days	86
<i>Dendroica pensylvanica</i> —Chestnut-sided		
Warbler .....	10-11 days	3
<i>Dendroica pensylvanica</i> —Chestnut-sided		
Warbler .....	13? days	183
<i>Dendroica virens</i> —Black-throated Green		
Warbler .....	12 days	3
<i>Black-throated Green Warbler</i> .....	12-14 days	87
<i>Dendroica palmarum hypochrysea</i> —Yellow		
Palm Warbler .....	12 days	3
<i>Dendroica discolor</i> —Prairie Warbler ..	14? days	3
<i>Seiurus aurocapillus</i> —Ovenbird .....	12 days	3
<i>Seiurus noveboracensis</i> —Water Thrush ..	14 days	1
<i>Geothlypis trichas trichas</i> —Maryland		
Yellowthroat .....	12 days	3
<i>Icteria virens virens</i> —Yellow-breasted		
Chat .....	15 days	3
<i>Icteria virens virens</i> —Yellow-breasted		
Chat .....	12 days	1
<i>Setophaga ruticilla</i> —Redstart .....	12 days	3
<b>Tanagridae</b>		
<i>Scarlet Tanager</i> .....	13 days	35
<i>Pyranga rubra</i> —Summer Tanager .....	12 days	1
<b>Ploceidae</b>		
<i>Lagonosticta minima</i> —Blood		
Finch .....	“about a fortnight”	1
<i>Lagonosticta minima</i> —Blood Finch .....	12 days	116
<i>Hypantica sanguinerostris</i> —Blutschnabel-		
weber .....	11 days	162
<i>Poëphila gouldie</i> —Grass Finch .....	12-13 days	116
<b>Icteridae</b>		
<i>Dolichonyx oryzivorus</i> —Bobolink .....	10 days	3
<i>Molothrus ater</i> —Cowbird .....	“nearly a fortnight”	1
Cowbird .....	10-11 days	74
<i>Molothrus ater ater</i> —Cowbird .....	10 days	3
<i>Argentine Cowbird</i> .....	11½ days	74
<i>Xanthocephalus xanthocephalus</i> —Yellow-		
headed Blackbird .....	10? days	3
Yellow-headed Blackbird .....	10? days	75

Family—Species		Period	Authority
<i>Agelaius phoeniceus phoeniceus</i> —Red-winged Blackbird	.....	10-14 days	3
<i>Strunella magna magna</i> —Meadowlark	.....	15-17 days	3
<i>Strunella neglecta</i> —Western Meadowlark	.....	15 days	3
<i>Icterus cucullatus nelsoni</i> —Arizona Hooded Oriole	.....	12-14 days	3
<i>Icterus spurius</i> —Orchard Oriole	.....	12 days	3
<i>Orchard Oriole</i>	.....	12-14? days	72
<i>Icterus galbula</i> —Baltimore Oriole	.....	14 days	1
<i>Icterus galbula</i> —Baltimore Oriole	.....	14 days	3
<i>Icterus bullocki</i> —Bullock's Oriole	.....	14 days	3
<i>Euphagus carolinus</i> —Rusty Blackbird	.....	14 days	3
<i>Euphagus cyanocephalus</i> —Brewer's Blackbird	.....	14 days	3
Brewer's Blackbird	.....	12 days	43
<i>Quiscalus quiscula quiscula</i> —Purple Grackle	.....	14 days	3
<i>Quiscalus quiscula aeneus</i> —Bronzed Grackle	.....	13-16 days	3
<i>Megaquiscalus major major</i> —Boat-tailed Grackle	.....	15 days	3
<i>Megaquiscalus major macrourus</i> —Great-tailed Grackle	.....	15 days	3
<b>Fringillidae</b>			
<i>Hesperiphona vespertina vespertina</i> —Evening Grosbeak	.....	13-14 days	3
<i>Coccothraustes vespertina</i> —Evening Grosbeak	.....	14? days	76
<i>Ligurinus chloris</i> —Greenfinch	.....	14 days	1
<i>Fringilla coelebs</i> —Chaffinch	.....	12 days	1
<i>Pyrrhula europaea</i> —Bullfinch	.....	13 days	1
<i>Erythrosipa githaginea</i> —Trumpeter Bullfinch	.....	“within a fortnight”	1
<i>Carpodacus purpureus</i> —Purple Finch	.....	13 days	3
<i>Carpodacus mexicanus frontalis</i> —House Finch	.....	exactly 14 days	77
<i>Carpodacus mexicanus frontalis</i> —House Finch	.....	13? days	3
<i>Loxia pityopsittaeus</i> —Parrot Crossbill	.....	14-15 days	1
<i>Loxia curvirostra</i> —Crossbill	.....	14 days	1
<i>Linota cannabina</i> —Linnet	.....	14 days	1
<i>Astragalinus tristis tristis</i> —Goldfinch	.....	12-14 days	3
<i>Carduelis elegans</i> —Goldfinch	.....	13-14 days	1
<i>Toeniopygia castanotus</i> —Chestnut-eared Finch	.....	14 days	14
<i>Emblema picta</i> —Painted Finch	.....	“took exactly 14 days”	17
<i>Chrysomitris spinus</i> —Siskin	.....	13-14 days	1

Family—Species	Period	Authority
<i>Sycais flaveola</i> —Saffron Finch.....about 14 days	97	
<i>Serinus Canarius</i> —Canary.....13-14 days	1	
<i>Serinus Canarius</i> —Canary.....exactly 14 days	78	
<i>Canary</i> .....13-14 days	54	
<i>Canary</i> .....14 days	8	
<i>Serinus canarius</i> —Canary.....14 days	171	
<i>Serinus hortulanus</i> —Serin.....13 to 14 days	1	
<i>Passer domesticus</i> —House Sparrow.13 and 14 days	1	
<i>Passer domesticus</i> —European House Sparrow.....12-14 days	3	
<i>Passer domesticus</i> —English Sparrow...12-13 days	104	
<i>Passer luteus</i> .....13-14 days	116	
<i>Plectrophenax nivalis nivalis</i> —Snow Bunting .....	21?	days 3
<i>Poaeetes gramineus gramineus</i> —Vesper Sparrow .....	11-13	days 3
<i>Passerculus sandwichensis savanna</i> —Savannah Sparrow.....	12	days 3
<i>Chondestes grammacus strigatus</i> —Western Lark Sparrow.....	“12 days or more”	43
<i>Zonotrichia albicollis</i> —White-throated Sparrow .....	12-14	days 3
<i>Spizella passerina passerina</i> —Chipping Sparrow .....	10-12	days 3
<i>Chippy</i> .....	10	days 72
<i>Spizella pusilla pusilla</i> —Field Sparrow...13 days	3	
<i>Field Sparrow</i> .....	“12 days or more”	43
<i>Junco hyemalis</i> —Slate-colored Junco...11-12 days	3	
<i>Melopsiza melodia melodia</i> —Song Sparrow .....	10-14	days 3
<i>Melopsiza georgiana</i> —Swamp Sparrow...13 days	3	
<i>Passerella iliaca schistacea</i> —Slate-colored Fox Sparrow.....	12-14	days 3
<i>Papilo erythrophthalmus erythrophthalmus</i> —Towhee .....	12-13	days 197
<i>Cardinalis cardinalis cardinalis</i> —Cardinal .....	12	days 3
<i>Cardinalis cardinalis cardinalis</i> —Cardinal .....	12-14?	days 79
<i>Paroaria cucullata</i> .....	14	days 116
<i>Paroaria larvata</i> .....	14	days 116
<i>Subernatrix cristata</i> .....	14	days 116
<i>Volatinia jacarini</i> .....	10?	days 116
<i>Zamelodia ludoviciana</i> —Rose-breasted Grosbeak .....	14	days 3
Rose-breasted Grosbeak .....	9??	days 43
<i>Coryphospiza cruentus</i> —Purpurkronfink..11 days	162	
<i>Passerina cyanea</i> —Indigo Bunting.....12 days	3	

Family—Species	Period	Authority
Indigo Bird .....	10? days	35
Passerina amaena—Lazuli Bunting.....	12 days	3
Passerina eiris—Nonpareil.....	14? days	80
Emberiza citrinella—Yellow Hammer.....	14 days	1

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#### ERRATUM—

Pages 52 to 57, inclusive—Read “Temperature” for “Weight” at heads of second columns.













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